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Dust Control at Hazardous Waste Sites

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HANDBOOK

DUST CONTROL AT HAZARDOUS WASTE SITES

by

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DISCLAIMER

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs, and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments, and the needs of both large and small businesses in handling their wastes responsibly and economically.

This report presents information useful in identifying sources of and controlling contaminated fugitive dust originating from contaminated land surfaces. The handbook is intended for use by hazardous waste site managers and is organized around three major dust reentrainment mechanisms. Control of vehicle reentrainment emissions, cleanup activity emissions, and wind erosion emissions are discussed.

David G. Stephan, Director
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ABSTRACT

This handbook describes methods of controlling contaminated fugitive dust originating from contaminated land surfaces. The contaminated dust may be reentrained by three basic mechanisms: vehicle reentrainment, cleanup activities, and wind erosion.

The use of this handbook will allow hazardous waste site managers to, first, assess what type of dust emission mechanism may be at work at the site and, second, formulate a plan to control that dust. Subjects covered under vehicle emissions include quantification of emissions, proper roadbed construction, the use of chemical dust suppressants, and proper housekeeping practices. Subjects covered under active cleanup and wind erosion emissions also include quantification of emissions as well as the use of water and chemically amended sprays in controlling emissions. Windscreens, liners, and mulches are also discussed as means of controlling wind erosion emissions. Cost data are included for all control strategies.

The handbook contains information on equipment decontamination and worker protection, in addition to a discussion of possible non-air impacts arising from the use of dust suppressant measures.

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SECTION 1

INTRODUCTION

Spills, waste disposal, and various industrial operations can contaminate land surfaces with toxic chemicals. Soil particles from these contaminated surfaces can, in turn, be entrained into the air, transported offsite by the wind, and result in human exposure by direct inhalation. Indirect exposure also can result if these particulates are deposited in agricultural fields, pastures, or waterways and thereby enter the human food chain. Two factors enhance this exposure route: 1) many of the environmentally troublesome compounds are tightly bound to particles; and 2) conditions at many surface-contaminated sites favor wind erosion, such as sparse vegetative cover and high levels of activity that disturb the surface.

The intent of this handbook is to assist hazardous waste site managers in identifying sources of fugitive dust and controlling that dust.

Contaminated soil can be reentrained to the air by three basic mechanisms:

1) Reentrainment by moving vehicles (rubber tired or tracked vehicles) on paved or unpaved roads

2) Cleanup activities (movement of soil by dozers, loading by front-end loaders)

3) Wind erosion

These three mechanisms can act separately or in any combination. For example, a site awaiting cleanup may be fenced and inaccessible to men or machinery; however, wind erosion is still possible. During cleanup activities, all three mechanisms may be at work. Different dust suppressant techniques are used to treat each mechanism.

This handbook is organized around the three major dust reentrainment mechanisms. Section 2 describes vehicle reentrainment emissions and control, Section 3 discusses cleanup activity emissions and control, and Section 4 discusses wind erosion emissions and control. Section 5 covers the preparation of a dust control plan. In Appendix A, matters relating to safe practices during and after dust suppressant application are discussed.

SECTION 2

CONTROL OF DUST REENTRAINED BY VEHICLE MOVEMENT

2.1 DUST PRODUCING MECHANISMS

Moving vehicles entrain dust in two ways: 1) the action of the tire grinds the road surface and forces particles backwards and up, and 2) the wind currents created by the moving vehicle cause dust from the roadway and the shoulder to be lifted up. Thus, both the road and the road shoulder must be treated. Unpaved roads must be as compacted (no loose particles) as possible to minimize the amount of loose particles to be reentrained; paved roads must be kept clear of windblown dust and spills. In both cases, the shoulders along the roadway must be as compacted as possible to make it difficult for wind currents to entrain particles.

2.2 QUANTIFICATION OF EMISSIONS

The following equation can be used to determine the emission factor for an uncontrolled unpaved road (EPA 1982a):

$$E = k(5.9)\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5} \qquad \text{(Eq. 2-1)}$$

where
- E = Emissions, lb of $\leq$ 30-micrometer particles
- k = Particle size multiplier (dimensionless) = 0.80
- s = Silt (particles <70 um) content of road surface material, %
- S = Mean vehicle speed, mph
- W = Mean vehicle weight, tons
- w = Mean number of wheels

The following equation can be used to determine the emission factor for paved roads (EPA 1982a):

$$E = k(0.090)\ I\left(\frac{4}{n}\right)\left(\frac{s}{10}\right)\left(\frac{L}{1,000}\right)\left(\frac{W}{3}\right)^{0.7} \qquad \text{(Eq. 2-2)}$$

where E = Emissions, lb of $\leq$ 30-micrometer particles
k = Particle size multiplier (dimensionless) = 0.86
I = Industrial augmentation factor (dimensionless), ranging from 1.0 to 7.0, usually 3.5
n = Number of traffic lanes
s = Surface material silt content, %
L = Surface dust loading, lb/mile
W = Average vehicle weight, tons

Particles $\leq$30 micrometers in size are the particles likely to stay in the air at distances greater than several hundred yards from the source. Particles greater than 100 micrometers usually settle out within 20 to 30 feet of the edge of the road. Particles 30 to 100 micrometers in size are likely to settle out within a few hundred feet of the road.

An examination of the variables in the equation enables one to analyze the factors that influence dust emissions. Emissions from unpaved roads increase with increases in the silt content in the road surface material, vehicle speed, vehicle weight, and the number of wheels. Emissions from paved roads increase with increases in the silt content of the surface material, the quantity of material on the road, and vehicle weight. Although speed is also probably a factor on paved roads, it did not meet the statistical requirements for entry into the equation.

2.3 PRINCIPLES OF CONTROL

2.3.1 Unpaved Roads

Fugitive dust from unpaved roads is made up of fine soil particles coming out of the roadway, and dust suppressants act to compact these particles together to keep them from being entrained in the air. Such compaction is highly dependent on the size gradation of the aggregate materials in a roadway. A road surface will not compact unless the range of particle sizes from small to large is in the correct proportion. This proper size gradation for an unpaved roadway surface is shown in Table 2-1, and the results of improper size gradation are shown in Table 2-2.

As indicated in Table 2-2, proper compaction cannot be achieved with any of the conditions listed. With too much gravel, relatively little dust will occur (until tires grind the gravel down to silt size particles), but the aggregate will be pushed to the side of the road. Any applied dust suppres-

TABLE 2-1. PROPER SIZE GRADATION FOR UNPAVED ROAD SURFACE

Sieve size	% Passing	Soil type
1 in.	100	Gravel
3/4 in.	85-100	
3/8 in.	65-100	
No. 4	55-85	
No. 10	40-70	Sand
No. 40	25-45	
No.200	10-25	Clay, silt

TABLE 2-2. RESULTS OF IMPROPER SIZE GRADATION

Material in excess	Bearing capacity	Amount of dust	When wet	Action of dust suppressant
Gravel	Good	Little	OK	Drains through top level of soil. Provides little control.
Sand	Poor	Some	Soft	Drains through top level of soil. Provides little control.
Silt/clay	Very poor	Large	Mud/ruts/ slippery	May not penetrate. Will aggravate mud, ruts, and slippery conditions.

sant will simply pass through the top surface and provide little control. With too much sand, the bearing capacity will be poor, and any dust suppressant that attempts to form a crust will not work because of rutting. The worst dusting occurs under the most common condition--that is, too much silt and clay--because dust suppressants tend to have trouble penetrating the surface. Also, when it rains the road will be muddy and slippery, and rutting will occur; all of these conditions are worsened by the dust supressant.

When dust control is required, roadway samples should be taken to determine size gradation. If the roadway aggregate does not meet the specifications on Table 2-1, additional aggregate of the missing sizes should be added. Without the proper size gradation of particles, no chemical dust suppressant or watering efforts will be successful.

2.3.2 Paved Roads

Reentrained dust from paved roads is controlled by removing dirt from the road surface by sweeping, vacuuming, or flushing. Unfortunately, all these methods remove coarse particles more successfully than fine particles. Thus in any paved road dust control program, emphasis must be placed on removing the fine material from the street.

2.4 FUGITIVE DUST CONTROL METHODS AND COSTS

2.4.1 Unpaved Roads

The dust controls used on unpaved roads are water, chemical suppressants, speed control, good housekeeping practices, and paving. Each of these methods is discussed briefly in this subsection.

Watering--

Water should be applied to the unpaved road surface with a water wagon or spray bar. The quantity will vary with the road surface material, sunlight, humidity, and traffic level. (See Section 2.5.1)

Chemical Dust Suppressants--

A comprehensive survey questionnaire indicated that about 40 manufacturers market various products for suppression of unpaved road dust. Available products were divided into four categories, based on their method of dust control and chemical similarity.

1) Salts--Hygroscopic compounds that extract moisture from the atmosphere and dampen the road surface; e.g., calcium chloride, magnesium chloride, hydrated lime, and sodium silicates.

2) Surfactants--Substances capable of reducing the surface tension of the transport liquid and thereby allowing available moisture to wet more dirt particles per unit volume; e.g., soaps, detergents, Dustset, and Monawet.

3) Adhesives--Compounds that are mixed with native soils to form a new surface; e.g., calcium lignon sulfonate, sodium lignon sulfonate, and ammonium lignon sulfonate.

4) Bitumens--Compounds derived from petroleum that are mixed with native soils to form a new surface; e.g., Coherex, asphalt, and oils.

Although these categories are not mutually exclusive, most products have a predominant characteristic that allows them to be so classified.

Salts, adhesives, and bitumens can be applied topically (sprayed on the road surface) or mixed in place (blade mixed with the top 4 to 6 inches of the roadbed) at intervals of weeks or months. Surfactants are routinely added to the water in water wagons and applied at regular intervals.

Selection of a chemical dust suppressant depends on the type of roadway aggregate, as shown in Table 2-3.

TABLE 2-3. BEST CHEMICAL DUST SUPPRESSANT CONTROL TYPE BY ROAD SURFACE SIZE GRADATION

Road Surface	Control
Excess Gravel	Water
Excess Sand	Bitumens
Good Gradation	Any
Excess Silt	Rebuilding of Road

Product names, application method and rate, dilution, and costs are shown in Table 2-4. This table also provides the telephone number of the main office of each product manufacturer. In many cases, the manufacturer will have a local representative who can assist in developing application procedures. The local representative may also have an applicator or can recommend a local applicator; however, the operator of the hazardous waste site can apply the dust suppressant if the proper equipment is available.

The products shown in Table 2-4 represent suppressants that were available in early 1984. The nature of the business is such that product manufacturers come and go quickly. Therefore, some products may no longer be available, whereas some new products may not be listed. Listing of these products does not constitute an endorsement.

Roadway Preparation--

Regardless of whether water or chemicals are used, proper roadway preparation is essential for dust control. Preparation steps include adding aggregate to the surface as required to obtain the size gradation in Table 2-1, and grading the road with a center crown and no low spots for water to collect.

Grading will probably be required every 1-2 weeks with watering. With chemical suppressants, grading after application of the dust suppressant will almost totally destroy control effectiveness; therefore, an excellent final grade should be put on the road before the final chemical spray. The road should not be regraded until just before the second chemical application (weeks after the initial application).

Spray Equipment--

Chemical dust suppressants and water are most commonly applied with water wagons equipped with two to five nozzles that shoot a flat spray behind the vehicle. The flow-control system is often crude and difficult to regulate, and it is not usually tied to vehicle speed. Therefore, it is difficult to regulate the quantity of material sprayed. Nonetheless, it is by far the most common method used.

A calibrated spray bar is more suitable for the application of chemical dust suppressants. The most sophisticated systems allow the operator to specify an application rate and the truck will automatically regulate the speed and spray rate. Some (but not all) bitumens must be applied with an asphalt distributor because the material must be heated before application.

Costs--

Certain costs are incurred in all dust suppressant programs. These include labor and material costs associated with road surface preparation, cost of the dust suppressant used, application costs, and road maintenance costs (grading, watering, and supplementing aggregate).

TABLE 2-4. DUST SUPPRESSANTS FOR UNPAVED ROADS[a]

Product	Address and telephone number of manufacturer	Application method: Topical	Application method: Mixed in place	Application rate: Dilution[b]	Application rate: Applied gal or lbs/yd²[c]	FOB price before dilution $/gallon
			Salts			
Dowflake	Dow Chemical Larkin Laboratory Midland, MI 48640 (517) 636-0949	X	X	NA	1.55	0.0725
DP-10	Wen-Don Corp. P. O. Box 13905 Roanoke, VA 24038 (703) 982-0561	X		None	0.5	1.95
Dust Ban 8806	Nalco Chemical Co. 2901 Butterfield Rd. Oak Brook, IL 60521 (321) 887-7500	X		None	0.25-0.5	0.22
Dustgard ($MgCl_2$)	Great Salt Lake Minerals and Chemicals Corp. P. O. Box 1190 Ogden, UT 84402 (801) 731-3100	X	X	None	0.5	0.24

(continued)

Table 2-4 (continued)

Product	Address and telephone number of manufacturer	Application method		Application rate		FOB price before dilution $/gallon
		Topical	Mixed in place	Dilution[b]	Applied gal or lbs/yd^2[c]	
		Salts (continued)				
Liquidow	Dow Chemical Larkin Laboratory Midland, MI 48640 (517) 636-0949	X	X	None	0.27-0.6	0.20
Sodium Silicate (N)	The PQ Corporation P. O. Box 840		X	4:1	NA	0.69
Sodium Silicate (O)	Valley Forge, PA 19482 (215) 293-7200		X	4:1	NA	0.71
		Surfactants				
MO70E	Mona Industries, Inc. P. O. Box 425 76 E. 24th Street Paterson, NJ 07544 (210) 345-8220	X		NA	NA	6.30
Sterox DF/ND/NJ	Monsanto Company 800 N. Lindbergh Blvd. St. Louis, MO 63166 (314) 694-1000	X		NA	NA	6.35

(continued)

Table 2-4 (continued)

Product	Address and telephone number of manufacturer	Application method		Application rate		FOB price before dilution $/gallon
		Topical	Mixed in place	Dilution[b]	Applied gal or lbs/yd^2[c]	
		Adhesives				
Bio Cat 300-1	Applied Natural Systems 35 E. Lake Mead Drive Henderson, NV 89015 (702) 451-6010	X	X	66:1	2.0	19.95
DCL-1801	Calgon Corp. P. O. Box 1346	X	X	66-200:1	0.5-0.8	9.20
DCL-1803	Pittsburgh, PA 15230 (412) 777-8000	X	X	100-200:1	0.5-0.8	30.64
Dust Bond 100	Research Products, Inc. 4222 North 39th Ave. Phoenix, AZ 85019 (602) 269-7891	X	X	None	0.17	0.40
Dust-Set	Mateson Chemical Corp. 1025 East Montgomery Ave. Philadelphia, PA 19125 (215) 423-3200	X	X	500:1	0.17	8.00
Dustbinder 124	Union Carbide Corp. Mining Chemicals 270 Park Ave. New York, NY 10017 (203) 794-2000	X		10-15:1	1.0	4.50

(continued)

Table 2-4 (continued)

Product	Address and telephone number of manufacturer	Application method		Application rate		FOB price before dilution $/gallon
		Topical	Mixed in place	Dilution[b]	Applied gal or lbs/yd^2 [c]	
		Adhesives (continued)				
Flambinder	Flambeau Paper Comapny P. O. Box 340 Park Falls, WI 54552 (715) 762-3231	X	X	5.5:1	0.5	0.15
Haul Road Dust Control	Midwest Industrial Supply, Inc. P. O. Box 8431 Canton, OH 44711 (216) 499-7888	X		33:1	NA	3.75
Lignosite	Georgia-Pacific Corp. P. O. Box 1236 Bellingham, WA 98227 (206) 733-4410	X	X	4:1	0.5	152.00/ton
Norlig A	Reed Lignin, Inc. 120 East Ogden Ave.	X	X	1.1	2.8	0.765
Norlig 12	Suite 106 Hinsdale, IL 60521 (312) 887-9640	X	X	2.4 lbs/gal.	2.8	0.228/lb
Orzan AL-50/Orzan DSL/ Orzan GL-50	Crown Zellerbach Corp. Chemical Products Division Camas, WA 98607 (206) 834-444	X	X	10:1	1.2-6.3	0.20

(continued)

Table 2-4 (continued)

Product	Address and telephone number of manufacturer	Application method: Topical	Application method: Mixed in place	Application rate: Dilution[b]	Application rate: Applied gal or lbs/yd^2 [c]	FOB price before dilution $/gallon
	Adhesives (continued)					
Soil-Sement	Midwest Industrial Supply, Inc. P. O. Box 8431 Canton, OH 44711 (216) 499-7888	X		5:1	0.25	2.32
Soiltex	Protex Industries, Inc. 1331 West Evans Ave. Denver, CO 80223 (303) 935-3566		X	4:1	4.8	0.33
Suferm	Chevron Chemical Co. Sulfur Products 575 Market St. San Francisco, CA 94105 (415) 894-6723	X	X	None	0.2	1.88
WESLIG 120	WESCO Technologies, Ltd. P. O. Box 3880 San Clemente, CA 92672-1680 (714) 661-1142	X		6-10:1	0.25	0.42
Woodchem LS	Woodchem, Inc. P. O. Box A Oconto Falls, WI 54154 (414) 846-2839	X	X	None	1.5	0.17

(continued)

Table 2-4 (continued)

Product	Address and telephone number of manufacturer	Application method: Topical	Application method: Mixed in place	Application rate: Dilution[b]	Application rate: Applied gal or lbs/yd^2 [c]	FOB price before dilution $/gallon
Bitumens						
AMS 2200	ARCO Mine Sciences 1500 Market Street P. O. Box 7258 Philadelphia, PA 19101 (215) 557-2000	X	X	4:1	0.5	0.5
AMS 2300		X	X	1:1	0.75	0.75
Coherex	Witco Chemical Golden Bear Division P. O. Box 378 Bakersfield, CA 93302 (805) 393-7110	X	X	10:1	0.5	1.25
Docal 1002	Douglas Oil Co. 3160 Airway Ave. Costa Mesa, CA 92626 (714) 540-1111	X	X	2:1	0.1	0.67
Peneprime	Utah Emulsions Co. P. O. Box 248 North Salt Lake, UT 84054 (801) 292-1434	X		None	0.5	1.23
Petro Tac P	Syntech Products Corp. 520 E. Woodruff Ave. Toledo, OH 43624 (419) 241-1215	X	X	1:5	0.24-0.75	1.55

(continued)

Table 2-4 (continued)

Product	Address and telephone number of manufacturer	Application method		Application rate		FOB price before dilution $/gallon
		Topical	Mixed in place	Dilution[b]	Applied gal or lbs/yd²[c]	
		Bitumens (continued)				
Resinex	Neyra Industries, Inc. c/o Petroleum Products, Inc. P. O. Box 493 Valparaiso, IN 46383 (219) 465-1300	X	X	10:1	1.25-5.00	1.48
Retain	Dubois Chemical Co. 3630 East Kemper Road Sharonville, OH 45241 (513) 769-4200	X	X	10:1	0.5	5.55

[a] Products listed are not endorsed over products not listed.
[b] Water: product.
[c] Quantities are listed as gal/yd² for liquid products and lb/yd² for solid products

A recent study (PEDCO 1983) cited total costs of applying specific types of dust suppressants at a rate and frequency to achieve a 50 percent control level in a coal mine. Assumptions used for the analysis are shown in Table 2-5. The bases for these assumptions are as follows:

- Product costs which were obtained from each vendor, represent the least expensive per gallon cost available. Shipping costs represent the least expensive method of shipping to an eastern mine (southern Illinois) and a western mine (southern Wyoming). This removes geographic advantages.
- Labor and machinery values represent industry averages obtained from mine personnel. Rates vary by mine depending on local contracts and machinery type and age.
- Water was assumed to be free. This is an inaccurate assumption, but no reliable cost data could be found.
- Activity parameters (miles graded per hour, etc.) are industry averages and vary by mine. Identical parameters were used for all chemicals mixed in place, and a second set of activity parameters was used for all topical applications.

These assumptions were used to calculate costs associated with the use of chemicals and water for dust suppression. The analysis of chemical dust suppressants was limited to mixed and topical applications of calcium chloride and mixed-in-place applications of lignon.

Table 2-6 presents a comparison of the cost-effectiveness of four controls for achieving a minimum 50 percent control level. The limited results show that topically applied salt or mixed-in-place adhesive are more cost-effective than watering. The selection of dust suppressant strategies, however, should also be based on other considerations related to road construction and spillage, as explained later in Section 2.5.

Reapplications of the chemicals would probably result in higher control efficiencies than the initial application because residual traces of the control material still remain. Therefore, this analysis, which is based on initial applications, may overestimate the cost of a long-term chemical program. Watering has no such cumulative control effects. Also, the analysis was performed for a mine haul road, where heavy vehicles and high speeds make dust suppression more difficult than it would be at a typical hazardous waste site. The less frequent application at these sites might lower the estimated costs.

TABLE 2-5. ASSUMPTIONS FOR COST-EFFECTIVENESS ANALYSIS

			Time Factor, h/mile			
			Chemical application			
Activity	Cost item	Cost $/hr	Mixed	Topical	Water Application	Activity frequency
Application	Surface Preparation	75	16	8	0	Depends on effectiveness of individual product
	Application	45	8	2	0.15	
Maintenance	Grading	75	0	0	4	For water, once per week; for chemicals, once per application
	Subsequent Watering	95	0.15	0.15	0.15	For water, 1.5 applications per hour; for chemicals, one application per shift

TABLE 2-6. PRELIMINARY COST-EFFECTIVENESS COMPARISON TO ACHIEVE 50 PERCENT CONTROL

Control[b]	Cost of chemical application, $[a]/mile		Cost of grading, watering, $/week		Applications required to average 50% control	Cost per week,$	
	East	West	Grading	Water		East	West
Salt							
Mixed	7240	11,263	0	143	1 per 4 weeks	1953	2959
Topical	3260	5,058	0	143	1 per 4 weeks	958	1408
Adhesive							
Mixed	4813	7,644	0	143	1 per 4 weeks	1346	2054
Water			375	1710	120 per week	2085	2085

[a] Includes the cost of surface preparation, materials, and application. Material cost represents delivered cost in East (southern Illinois) and West (Rock Springs). These costs are: Liquidow, $0.36/gallon East, $0.47/gallon West; Flambinder $0.33/gallon East, $0.47/gallon West. Cost assumes 50-foot and 60-foot-wide road in East and West.

[b] Required application intervals could not be estimated for topical application of adhesive, surfactant, or bitumens based on the data available. Comparative costs could not be calculated.

Material delivery cost is a significant part of product cost. It can exceed the cost of the material. The smallest delivery quantity of most suppressants is a 55-gallon drum. The material must be pumped or poured in the applicator.

A more economical way to buy the material is in a tanker truck. If no onsite storage tank is available, the tank trailer can be left on site and the material pumped as required.

The material is also available by train tanker car. Again, on-site storage facilities are required, or the tanker car must be stored on a siding.

Vehicular Speed Control--

In Equation 2-1, the factor S/30 describes the effect of vehicular speed on dust emissions. For example, a change in speed from 30 to 20 mph would reduce emissions by 33 percent. Although this factor may overestimate emission reductions resulting from reduced speed, the principle holds. The cost of imposing speed control is increased labor and equipment time to haul material.

Housekeeping Practices--

Housekeeping refers to cleaning up spills and track-on material left by the trucks. These materials will not have been treated by the dust suppressant (water or chemical) and are thus easily reentrained. Costs include labor and equipment time to remove.

The best way to minimize housekeeping is to minimize spills and carryout. Measures to minimize spills include the use of trucks with tailgates as opposed to scows, eliminating truck leaks, not overfilling trucks, and covering loads. The best way to minimize carryout is to eliminate muddy areas by regrading or gravelling them, and by installing a truck tire and underbody wash over a grate and requiring all trucks to pass through it.

Paving--

The base emission factor (constant coefficient) for an unpaved road versus a paved road (see Equation 2-1 and 2-2) is 5.9 lb/mile traveled versus 0.09 lb/mile traveled, a reduction of 98.5 percent. This control is far more efficient than water, chemicals, speed control or housekeeping. Maintaining this control efficiency, however, requires continued cleaning of the paved road.

Costs vary by area of the country and with the thickness of pavement required to support truck weight. The average cost of blacktopping a two-lane road suitable for over-the-road trucks is about $140,000 per mile, plus street cleaning costs.

2.4.2 Paved Roads

Paved roads become dirt-laden from spills, track-on, and windblown dust. The control methods used on these roads are manual cleaning, mechanical sweeping, vacuum sweeping, flushing, and general housekeeping practices. The objective of these efforts is to remove all loose dirt, particularly fine particles.

Manual Cleaning--

Manual cleaning may be adequate for short sections of road, but it is a very labor-intensive approach.

Mechanical Sweeping--

Mechanical street sweeping is the most common means of control; however, it is relatively ineffective in the removal of fine particles. In one series of tests, material consisting of particles 74 to 177 micrometers in size was applied to a paved street at a loading of 600 grains per square foot. Removal efficiency was 46 to 63 percent. Silt-size particles, (less than 74 micrometers) are the particles most likely to be entrained. Removal efficiency of mechanical sweeping for this size particle is probably less than 46 percent. In addition, the act of street cleaning itself creates dust because of the impact of the cleaning vehicle tires on the road, the brushing of dry pavement, and wind turbulence caused by exhaust and vehicle movement. Unless the street is very dirty, the net improvement in ambient air quality as a result of sweeping will be small or negative.

Vacuum Sweeping--

Vacuum sweeping is more efficient than mechanical sweeping. In the same experiment just discussed, collection efficiencies of 90 to 92 percent were observed. Again, collection efficiency would probably be less for silt-size particles, and again, some dust emissions are caused by the sweeper itself.

Street Flushers--

Street flushers hydraulically move street debris from the street surface to the gutter. Often flushing is used in conjunction with vacuum sweeping rather than as the sole method of cleaning. Flushing before sweeping washes street dirt to the curb for collection by motorized sweepers. When utilized in this manner, the flushing requires smaller quantities of water and lower nozzle pressures. The benefits of flushing after sweeping instead of before are that the entire pavement is made cleaner and only small quantities of dirt are washed into inlets and catch basins. Like sweeping, flushing is more effective in the removal of larger particles than fine particles.

Housekeeping Practices--

The same principles apply to paved roads as those for unpaved roads, i.e. measures to minimize material spillage and dirt track-on, and immediate cleanup when they do occur.

Summary--

It is recommended that a combination of vacuuming and flushing be used, with the flushing being performed after vacuuming. Dry sweeping should not be performed since the sweeping action will probably generate more dust than it will pick up.

The methods prescribed by the manufacturer for his vacuuming/sweeping equipment should be used, cognizant of the main objective of removing fines from the roadway.

2.5 CONTROL EFFECTIVENESS

2.5.1 Unpaved Roads

Watering/Surfactant--

As shown in the watering test results presented in Table 2-7, watering once per hour will normally have a control effectiveness of 50 percent. Watering twice per hour or once every two hours will have a control effectiveness of about 75 and 30 percent, respectively. Effectiveness may be greater during evening hours and during periods of high humidity.

No surfactant tests have been conducted, but efficiencies at the same level of water use should exceed those of plain watering. The objective of using a surfactant, however, is to reduce water consumption, and the effectiveness of less watering with a surfactant has not been tested.

TABLE 2-7. COMPARISON OF MEASURED CONTROL EFFICIENCIES

Control	No. of samples	Location of test	Vehicle type[a]	Time since application	Control efficiency	Particle size[b]	Reference
Water	3	I&S[c]	HD	0.5-4.5 h[d]	96-55	TP	EPA 1982b
					98-50	IP	
					98-61	FP	
	9	Coal Mine	HD	0-1 h	69-59	SP	EPA 1981b
					73-61	IP	
					58-54	FP	
	3	Coal Mine	HD	0-0.5 h	88	TSP	ARCO 1980
				0-0.25 h	97	TSP	
	26	Coal Mine	HD	0.3-1.0 h	75-25	TSP	TRC 1981a
	3	I&S	HD	1.0-4.8	98-61	TP	EPA 1983
					98-78	IP	
					98-79	PM_{10}	
					96-67	FP	
	24	Coal Mine	HD	0.5-2.0 h	77-12	TSP	PEDCo 1983
	12			1.0-2.0 h	66-31	IP	
	24			0.5-2.0 h	60-15	FP	
Bitumens	2	I&S	LD	< 1 day	97-84	TSP	EPA 1979
					97-83	FP	
	4	I&S	HD	0-48 h	98-92	TP	EPA 1982b
					96-91	IP	
					97-90	FP	
	5	I&S	LD	25-51 h	100-94	TP	EPA 1982b
					99-91	IP	
					97-94	FP	
	2	I&S	NR	28-29 days[e]	95-90	TP	USS 1981
	24	Other	LD	0-3.5 mo	80-0	TSP	EPA 1981a
	24	Other	LD	0-3.5 mo	86-36	TSP	EPA 1981a
	4	Coal Mine	HD	0-3 days	89-59	TSP	ARCO 1980
	4	Coal Mine	HD	3.5 weeks	35	TSP	ARCO 1980
	8	I&S	HD	2-116 days	100-21	TP	EPA 1983
					100-0	IP	
					100-0	PM	
					99-0	FP^{10}	

(continued)

Table 2-7 (continued)

Control	No. of samples	Location of test	Vehicle type[a]	Time since application	Control efficiency	Particle size[b]	Reference
	8	I&S	HD	7-77 days	87-16	TP	EPA 1983
					86-22	IP	
					97-36	PM_{10}	
					100-25	FP	
	4	I&S	HD	4-35 days[f]	98-88	TP	EPA 1983
					98-91	IP	
					100-90	PM_{10}	
					100-25	FP	
	30	Coal Mine	HD	1-4 weeks	64-0	TSP	PEDCo 1983
	18				85-0	IP	
	30				88-0	FP	
Adhesives	36	Coal Mine	HD	1-4 weeks	80-0	TSP	PEDCo 1983
	25				91-0	IP	
	36				75-0	FP	
Salts	1	Coal Mine	HD	3 mo[g]	95	TSP	EPA 1981b
					95	IP	
					88	FP	
	34	Coal Mine	HD	1-7 weeks	83-0	TSP	PEDCo 1983
	26				74-0	IP	
	34				80-0	FP	
Surfactants	27	Coal Mine	HD	1-6 weeks	87-0	TSP	PEDCo 1983
	20				68-0	IP	
	27				85-0	FP	

[a] HD = heavy-duty; LD = light-duty; NR = not reported.
[b] TP = total particulate; TSP = total suspended particulate (<39 μm); IP = inhalable particulate (<15 μm). PM_{10} = particulate matter <10 μm., FP = fine particulate (<2.5 μm).
[c] I & S = iron and steel facility.
[d] Testing began at 3:00 p.m. and continued past dusk.
[e] Time since third application.
[f] Time since second application.
[g] Road was watered prior to test.

The water application recommended for obtaining the near 100 percent control needed at some sites is 0.125 gallon/yd^2 every 20 minutes. If muddy conditions develop, frequency should be reduced to 30 minutes (or more as possible) to achieve nearly total dust control.

Chemical Dust Suppressants--

Data on the effectiveness of chemical dust suppressants is also shown in Table 2-7. These data vary widely depending on the number of days since the last application, application rates, traffic volumes, vehicle size, the receiving surface, and testing methodologies. In the first week after application, efficiencies of 80 percent or greater can be achieved. After one month, values of 40 to 60 percent are common under heavy-duty vehicle use. All of these values represent initial applications. Almost no testing has been performed after chemical reapplications, and the values could reasonably be expected to be higher.

From an air quality perspective, the relative merits of topical application versus mixed-in-place application are unclear. The author's experience has shown that the salt and bitumen generally perform better when topically applied, whereas, the lignon mixed-in-place sections were superior. A possible explanation (based on visual observation) is that the road surface is generally compacted prior to the application of the chemicals. Whereas topical application does not disturb this compaction, scarifying and subsequent windrowing and blading associated with mixed-in-place application does initially result in a less compacted surface. Visual observations indicated that the lignon appeared to bind the surface more quickly than did the salt. A period of time was required for the salt to draw moisture from the atmosphere, recompact the road surface, and attain maximum effectiveness.

In light of the greatly higher costs involved with mixed-in-place application as opposed to topical application, these test results suggest that the salt and bitumens should be applied topically. At any rate, mixed-in-place application is usually only recommended at the time of initial application.

As a means of achieving the total control of dust necessary at some hazardous waste sites, it is recommended that a second chemical dust suppressant application be made 4 to 10 days after the initial application. The elapsed time should be based on observation. Time between applications can be gradually lengthened to about 30 days if spillage and track-on are being controlled.

Chemicals versus Water--

A comparison of hourly watering with the application of chemical dust suppressants every 4 weeks plus once/shift watering shows that costs and control efficiencies are similar, depending on the chemical used (previously cited Table 2-6). Other considerations that can affect the control selection are presented in Table 2-8. Chemicals may often be the material of choice, because contaminated water runoff from the road can present a problem with the large amount of water necessary when water alone is used as a control measure.

Chemical dust suppressants are not feasible, however, at sites where road construction is so poor that the road must be regraded or rebuilt with new aggregate after all major storms. Regrading or rebuilding almost totally destroys the effectiveness of any applied chemicals; thus, thousands of dollars of chemicals could conceivably be wasted within days after their application.

2.5.2 Paved Roads

To date, control effectiveness testing has been mainly directed toward the effectiveness of the sweeping of city streets in lowering ambient air quality. City streets are relatively clean to begin with in comparison with paved industrial roads, which would be more comparable to the paved roads used for material hauling at a hazardous waste site.

Based on test results of cleaning nonindustrial streets in several cities, it appears that mechanical sweeping of paved roads makes no significant difference in ambient air quality; if anything, it may make air quality slightly worse because more dust is generated during the sweeping than is removed from the road.

Sweeping of paved industrial roads is much more limited. Based on four exposure profile tests per control in a steel mill, the highest measured value for the control efficiency of vacuum sweeping, which occurred 2.8 hours (mid-point of test) after vacuuming, was 69.8 percent for total particulate (TP) (EPA 1983). In another test, a control efficiency of 16.1 percent was measured 4.1 hours after vacuuming. The control efficiency for water-flushing at 2.2 liters/m^2 (0.48 gal/yd^2) was 54.1 percent for TP approximately 40 min after application. A subsequent test showed a value of 44.1 percent after 3.6 hours. The control efficiency for flushing and broom-sweeping approximately

TABLE 2-8. CHEMICALS VERSUS WATER AS A DUST CONTROL MEASURE

Item	Evaluation
Control effectiveness	Similar
Cost	Chemicals are often lower in total cost.
Contaminated water runoff	Chemicals create less of a problem.
Material spills	Water is better
Trackout	Chemicals are better
Maintenance	Chemicals are better
Freezing Weather	Chemicals are better

40 min after water was applied at 2.2 liters/m^2 (0.48 gal/yd^2) was 69.3 percent for TP. The control efficiency fell to 34.6 percent after 2.8 hours. The drop in control efficiency on a paved road is more a function of how much material is being deposited on the road from spilling and windblown dust, than actual decay in control efficiency (assuming control measurements are made under dry road conditions). Because some of the steel plant tests were performed immediately after flushing, however, some of the control being measured is probably the effect of moisture.

SECTION 3

CONTROL OF EMISSIONS FROM SOIL MOVEMENT

Movement of dirt at a hazardous waste facility could consist of bulldozers moving soil or front-end loaders loading soil into trucks for removal elsewhere on the site or offsite. Control of emissions from trucks was discussed in Section 2. The purpose of this section is to discuss emissions from dozers, front-end loaders, and material dumping into trucks.

3.1 DUST PRODUCING MECHANISMS AND PRINCIPLES OF CONTROL

3.1.1 Bulldozers

The tracks and blade of a bulldozer are the sources of emissions. Bulldozer tracks reentrain dirt in much the same manner as wheels, except the grinding action is probably greater. The top and sides of the blade generate emissions as dirt slides off. This is particularly true of the top of the blade, where thin layers of dirt can easily be carried off by the wind.

3.1.2 Front-End Loaders

Emissions from front-end loaders emanate from the tracks or wheels as well as the loader bucket. The usual source of emissions from the loader bucket results from spillage as the bucket is being raised.

3.1.3 Soil Drop

The soil drop creates two sources of dust: 1) when a mass of dirt is being dropped, the wind picks up soil particles from the edges of the mass; and, 2) air turbulence causes dust entrainment as the mass of dirt is dropped into the truck. In the latter case, the displacement of air up out of the truck caused by the mass of dirt moving downward, causes soil already in the truck to rise along with soil from the edge of the dirt mass being dropped.

3.2 QUANTIFICATION OF EMISSIONS

3.2.1 Bulldozers

An emission factor was developed for bulldozing activity on overburden in coal mines, where silt values ranged from 3.8 to 15.1 percent and moisture ranged from 2.2 to 16.8 percent. The emission factor which includes emissions from both the tracks and the blade, is as shown in the following equation (PEDCo 1981):

$$TSP = \frac{5.7\ s^{1.2}}{M^{1.3}} \qquad \text{(Eq. 3-1)}$$

where TSP = Emissions of total suspended particulate in lb/h
s = Silt, percent
M = Moisture, percent

3.2.2 Front-End Loader and Soil Drop

The emission factor for front-end loader operations given in EPA's Compilation of Air Pollutant Emission Factors (1982a) was developed based on material-handling operations at a steel mill. All sources (track, tires, bucket, dump) are represented by this factor, which is given as:

$$E = K(0.0018)\frac{\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)\left(\frac{H}{5}\right)}{\left(\frac{M}{2}\right)^{2}\left(\frac{Y}{6}\right)^{0.33}} \qquad \text{(Eq. 3-2)}$$

where E = TSP emission factor, lb/ton
K = Particle size multiplier (dimensionless) = 0.73
s = Material silt content, %
U = Mean wind speed, mph
H = Drop height, (ft)
M = Material moisture content, %
Y = Dumping device capacity, yd^3

The silt and moisture terms describe the general dustiness of the material being moved. Three of the variables deal with the material dump cycle. Emissions increase with higher wind speed (blowing of dirt from the dirt mass edges), greater drop height (more turbulence caused by material drop), and smaller bucket size (more dirt mass edge per unit of volume).

3.3 PRINCIPLES OF EMISSION CONTROL

3.3.1 Bulldozers/Front-End Loaders

As the soil is moved, new soil is continually exposed; therefore, the control measure must also be continuous, or at least at frequent regular intervals.

The only method of controlling these dust emissions is to spray the area being worked at frequent intervals (30 minutes to 2 or 3 hours). Water or surfactant (to minimize the amount of water) can be used, and it can be sprayed from a mobile tower. Spraying moistens the soil on the surface but not all the soil being moved; however, soil below the surface is frequently more moist than soil on the surface. The surface spray reduces emissions from the track or wheels, and also tends to reduce somewhat the emissions from the bucket and material drop.

Limited experiments have been made to try to attach sprays directly to bulldozers or front-end loaders; however, several operational problems occur. The machine must either be outfitted with a large tank or an umbilical cord to a tank, neither of which is desirable. The spray nozzles must be attached to the blade/bucket or on arms reaching over the blade/bucket. Maintenance is difficult with either approach. Lastly, machine operators object to working in the resulting misty conditions.

3.3.2 Material Drop

Although area spraying effects some reduction in emissions resulting from material drop, the spray does not treat the bulk of the material being dropped, and significant emissions are still present. Basic control methods are to induce moisture into the drop cycle (increasing the moisture term in Equation 3-1) and to decrease windspeed around the drop receptacle (decreasing the windspeed in Equation 3-1). Neither of these practices is widely used in truck loading, but they are commonly used in the aggregate industry during the dumping of material into surge bins.

The most efficient way to spray moisture on material being dumped, is to construct a mobile frame through which a truck can drive and the truck bed can be positioned under a series of nozzles. The flat spray from the nozzles forms a "spray curtain" across the entire horizontal surface of the truck box. The spray is operated only during the actual dump, and water, surfactant, or foam can be used. The edges of the soil mass are moistened as it is dumped through the spray curtain. More important, as the upward turbulance of air brings dirt upward out of the truck box, the generated dust is caught in the spray curtain and falls back into the box. The system is not operated continuously. It is turned on by the truck driver or (remotely) by the front-end loader operator.

The use of portable screens provides another way to control emissions from the dump cycle. The windscreen can be positioned to shield only the dump cycle or to shield both the dump cycle and the front-end loader operation. The screen height should exceed the height of the front-end loader bucket drop by at least a foot, and it should be two screen heights wider than the width of the area being worked. Screen porosity should be 50 percent. The screen will shelter a downwind distance of about 7 to 10 screen heights and reduce windspeed by as much as 50 percent at the surface. With regard to the bulldozer or front-end loader, the actual emissions are not reduced, but the lower windspeed causes the dust to drop back to the ground sooner. The same is true of the material drop cycle. If the plume from the material drop goes over the height of the screen, however no control is provided for that part of the plume. To the contrary, wind eddies from the windscreen may carry the dust even farther.

3.4 AVAILABLE CONTROL PRODUCTS

The primary available products are surfactants, which can be used for the area spray and for the spray curtain; foams, which can be used for the spray curtain; and windscreens. Data on these products are presented in Table 3-1.

3.4.1 Application Methods

Product vendors often sell spray nozzles, masts, and spray curtains, or can recommend places to purchase these items. They also can assist in the construction of systems.

For area spraying, a fiberglass fertilizer tank mounted on a trailer with a pump and portable generator makes a mobile system that can be pulled anywhere on site with a pickup truck. The surfactant can be mixed in the fertilizer tank; the sloshing of the liquid while pulling the trailer usually provides adequate mixing. The material can be reapplied when dust becomes visible from the bulldozer or front-end loader operations.

A spray curtain is more difficult to fabricate. For best results, it should be mobile so that it can be moved close to the excavation point to minimize front-end loader travel. The system can be mounted on a large frame under which a truck can drive, and it should surround each side of the truck box. Each side of the frame will contain two to eight nozzles, depending on the length of the truck to be loaded and the spray width of the nozzles. The

TABLE 3-1. SOIL MOVEMENT DUST SUPPRESSANTS

Product Name	Manufacturers' addresses, telephone numbers	Application method: Topically by truck	Application method: Topically by fixed mast	Application method: Mixed in place	Application method: Other	Application rate: Dilution	Application rate: Applied gal/yd²	FOB Price before dilution, $
Liquid chemicals (surfactant)								
Compound MR	Johnson-March Corp. 3018 Market Street Philadelphia, PA 19104 (215) 222-1411		X			1000:1	NA[a]	4.00/gal
Compound MR 20/40			X			2000-4000:1	NA	5.25/gal
DCF-20	Calgon Corp. P. O. Box 1346 Pittsburgh, PA 15230 (412) 777-8000		X			50-200:1	20-50 lb product to 1000 tons of material	4.76/gal
DCL-163			X				10-45 lb product to 1000 tons of material	9.26/gal
DCL-1870			X			1000-5000:1	2-10 lbs product to 1000 tons of material	14.58/gal
Dustalloy	Wen-Don Corp. P. O. Box 13905 Roanoke, VA 24034 (703) 982-0561		X			1000-2000:1	Not available	Not available
GCP 200	Betz Laboratories, Inc. Somerton Rd. Trevose, PA 19047 (215) 355-3300		X			b		
GCP 201			X			b		
GCP 202			X			b		

(continued)

Table 3-1 (continued)

Product Name	Manufacturers' addresses, telephone numbers	Application method: Topically by truck	Application method: Topically by fixed mast	Application method: Mixed in place	Application method: Other	Application rate: Dilution	Application rate: Applied gal/yd²	FOB Price before dilution, $
			Liquid chemicals (surfactant) (continued)					
M070E	Mona Industries, Inc. P. O. Box 425 76 E. 24th Street Paterson, NJ 07544 (210) 345-8220		X			Not available	Not available	6.30/gal
Sterox DF	Monsanto Company 800 N. Lindbergh Blvd. St. Louis, MO 63166 (314) 694-1000		X			Not available	Not available	6.35/gal
Sterox ND			X			Not available	Not available	6.35/gal
Sterox NJ			X			Not available	Not available	6.35/gal
			Foams					
Aquadyne Dust Suppression System	Motmoco, Inc. P. O. Box 300 Paterson, NJ 07543 (201) 345-6202		X			NA	NA	c
Chem-Jet	Johnson-March Corp. 555 City Line Avenue Bala Cynwyd, PA 19004 (215) 688-2800		X			NA	NA	c
Micro Foam	DeTer Company, Inc. 8 Great Meadow Lane E. Hanover, NJ 07936 (210) 386-1363		X			NA	NA	c

(continued)

Table 3-1 (continued)

Product Name	Manufacturers' addresses, telephone numbers	Application method: Topically by truck	Application method: Topically by fixed mast	Application method: Mixed in place	Application method: Other	Application rate: Dilution	Application rate: Applied gal/yd²	FOB Price before dilution, $
			Foams (continued)					
Omega Foam Dust Suppressant System	Valerin Technologies, Inc. Technical Center 87 Great Valley Parkway Great Valley Corp. Center Malvern, PA 19355 (215) 296-7322		X			NA	NA	c
Sonic Dry Fog	Sonic Development Corp. 305 Island Road Mahwah, NJ 07430 (210) 825-3030		X			NA	NA	c
M218	Dowell Division of Dow Chemical U.S.A. P. O. Box 4378 Houston, TX 77210 (800) 645-9355		X			NA	NA	c
			Windscreen					
Dusttamer	Julius Koch, Inc. P. O. Box A-995 New Bedford, MA 02741 (617) 995-9565				Windscreen	NA	NA	2.07-2.95/linear foot, 3-ft width

[a] NA = not applicable.
[b] Application and price information is confidential.
[c] Products are sold as turnkey systems. Price varies with application and size of system.

masts on which the nozzles are mounted should be adjustable in height so that they can accomodate different truck heights and different site grades. It is essential that the flat spray be directly over the top of the truck box. The system should only be turned on during actual dumping to avoid excessive liquid, and the nozzles should set for a flat spray instead of a mist, as a mist will not form a total spray curtain during windy conditions.

3.4.2 EFFECTIVENESS

PEDCo Environmental, Inc. (1984b) tested dust control measure effectiveness during movement of soil. Four control measures were evaluated. Control Measure 1 consisted of spraying the active working area of the front-end loader (FEL) and dump truck with water (0.9 gal/yd^2). Application procedures were the same for Control Measure 2, except that surfactant was added to the water to form a 1:1000 dilution of surfactant to water. Somewhat less watering was needed for these tests (0.75 gal/yd^2). Control Measure 3 consisted of an array of 12 spray nozzles on the sides of the dump truck, which emitted a spray curtain of a water/surfactant mixture of the same proportion. Mixture usage amounted to 1.5 gal/yd^3. This method was used to control emissions from the dump cycle. In Control Measure 4, four spray nozzles were placed at the corners of the truck bed to disperse a foam spray curtain, which was operated only during each dump. Quantities of liquid averaged 0.4 gal/yd^3.

The results of PEDCo's testing are summarized in Table 3-2. Water spraying over the area being worked by the FEL and truck resulted in a control efficiency of 42 percent for <30-μm particles (TSP) and 64 percent for <2.5-μm particles (FP). Surprisingly, the emissions from the dump cycle were reduced 63 and 70 percent for TSP and FP, respectively. Adding surfactant to the water increased control efficiencies slightly and allowed a reduction in the quantity of water used. The TSP control efficiency for FEL travel/scraping increased from 42 to 69 percent with the addition of the surfactant. Other control values showed smaller increases.

TABLE 3-2. SUMMARY OF CONTROL EFFECTIVENESS RESULTS[a]

Operation	Control Measure	Control Efficiency, %	
		Fine particulate	Total suspended particulate
Front-end loaders--traveling and scraping	Area spray-water (0.9 gal/yd²)	64	42
	Area Spray-Water/Surfactant (0.75 gal/yd²)	70	63
Front-end loaders--dumping	Area spray-water (0.9 gal/yd²)	66	69
	Area spray-water/surfactant (0.9 gal/yd²)	62	77
	Water curtain (1.5 gal/yd³0	56	50
	Foam curtain (0.4 gal/yd³)	41	46

[a] Source: PEDCo 1984b.

Both spray curtain control measures proved to be less effective than area spraying with a water/surfactant mixture; however, a redesign of the controls used could result in higher efficiencies. Of the two spray curtain measures, the water curtain provided somewhat better control of dust from the dump cycle than did the foam curtain. If one of these controls were used in conjunction with the water/surfactant area spray, the resulting control efficiency would probably be significantly greater than for either one alone.

Dryer conditions than those experienced during the testing would require greater quantities of water. Nevertheless it is unlikely that the goal of 100 percent control efficiency can be obtained with these technologies. Thus, the potential for subsequent human exposure to hazardous waste dust would still exist.

SECTION 4

CONTROL OF EMISSIONS FROM WIND EROSION

4.1 DUST PRODUCING MECHANISMS

Wind erosion of exposed areas or piles occurs in the following ways: soil transport by surface creep, saltation, and suspension. Surface creep describes the rolling and sliding movement of particles across a surface. These particles generally have a diameter in excess of 1000 μm. Saltation is a term used to describe the hopping and bouncing movement of a particle. These particles, which have diameters ranging from 80 to 1000 μm, are lifted by the wind but are too heavy to remain airborne. Particles smaller than 80 μm are generally moved by suspension. Sehmel (1980) determined that from 3 to 40 percent by weight of the total soil loss from exposed areas is attributable to suspension. Between 50 to 75 percent of these particles are moved by saltation, and surface creep accounts for 5 to 25 percent.

Wind erosion is usually an intermittent activity that occurs above a threshold wind velocity. Estimates of this threshold velocity vary from about 10 to 20 mph across different soil types, aggregates, and meteorological conditions.

4.2 QUANTIFICATION OF EMISSIONS

Various researchers have attempted (with limited success) to quantify emissions from exposed areas and piles.

4.2.1 Exposed Areas

The following wind erosion emission factor equation is the most commonly used to estimate emissions from exposed areas (EPA 1974):

$$E_s = AIKCL'V' \qquad \text{(Eq. 4-1)}$$

where: E_s = Suspended particulate fraction of wind erosion losses of tilled fields, tons/acre/year
a = Portion of total wind erosion losses that would be measured as suspended particulate, estimated to be 0.025
I = Soil erodibility, tons/acre/year
K = Surface roughness factor, dimensionless
C = Climatic factor, dimensionless
L' = Unsheltered field width factor, dimensionless
V' = Vegetative cover factor, dimensionless

Values of undefined variables can be found in the above reference. Values from this equation can range from .001 to 8.25 tons/acre-year, but generally range between .05 and .75 ton/acre-year. The equation is based on the premise that wind erosion varies with soil particle size (A), soil characteristics (I and K), moisture and windspeed (C), field width (L'), and vegetative cover (V').

4.2.2 Storage Piles

The following emission factor equation is the most commonly used for estimating erosion from storage piles (EPA 1979):

$$E = 1.7 \left(\frac{s}{1.5}\right) \left(\frac{365-p}{235}\right) \left(\frac{f}{15}\right) \qquad \text{(Eq. 4-2)}$$

where E = Total suspended particulate emission factor, lb/day/acre
s = Silt content of aggregate, %
p = Number of days/year with $\geq$ 0.01 in. of precipitation
f = Percentage of time that the unobstructed windspeed exceeds 12 mph at the mean pile height

The premise of the equation is that wind erosion emissions vary with soil particle size, moisture, and windspeed.

4.3 PRINCIPLES OF EMISSION CONTROL

Control systems work in one of two ways: by reducing windspeed on the soil surface, or by forming a new, less-erodible soil surface.

The following methods are used to reduce windspeed at the soil surface:

1) Covering the pile with a wind-impervious fabric or vinyl.

2) Erecting a windscreen.

3) Pile orientation and pile shape.

Methods of forming a new, less-erodible surface are:

1) Water spraying to compact and weight soil particles.

2) Application of chemical dust suppressants to form a crust over the existing soil or to bind the top soil particles together.

3) Establishment of vegetation. The roots bind the soil together, and the stems reduce windspeed at the surface.

These methods change the I, K, C, and V' factors in Equation 4-1.

4.4 AVAILABLE CONTROL PRODUCTS AND THEIR APPLICATION

Products for dust control of exposed areas and undisturbed storage piles are the same. Product categories are as follows:

1) Liners and geotextiles that are impermeable to the wind. Some are also impermeable to liquids.

2) Windscreens that decrease windspeed on the downwind side.

3) Spray systems that spray foam every few hours to cover or moisten the soil.

4) Application of liquid chemicals to form a soil admixture. These products, which are sprayed on every few weeks, include bitumens, adhesives, salts, or binders with grass seed.

Product names, manufacturers' addresses, phone numbers, application methods and costs are shown in Table 4-1.

4.4.1 Liners and Geotextiles

Liners will not allow water or many chemicals to pass. Geotextiles will allow liquids to pass, and may not be tolerant of certain chemicals. Because geotextiles are the more commonly used for prevention of soil erosion, chemical compatibility testing has not been performed. Some liners and geotextiles may also suffer from ultraviolet degradation when exposed to sunlight.

TABLE 4-1. EXPOSED AREA AND STORAGE PILE DUST SUPPESSANTS

Product name	Manufacturers' address and telephone numbers	Application method: Topically by truck	Application method: Topically by fixed mast	Application method: Mixed in place	Application method: Other	Application rate: Dilution	Application rate: Applied gal/yd²	FOB price before bilution, $
			Mulch, liners, fabrics					
Enviromat	International Minerals & Chemical Corp. 421 East Hawley Street Mundelein, IL 60060 (312) 566-2600				Liner	NA[a]	NA	4.50/yd²
Gagle Liner	Duane W. Gagle Co. P. O. Box 441 Bartlesville, OK 74003 (918) 337-0129				Liner	NA	NA	4.00-5.00/yd² installed
Mirafi Fabrics	Director of Mirafi Celanese Fibers Merketing 1211 Avenue of the Americas New York, NY 10036 (212) 719-8000				Fabric	NA	NA	0.90-1.20/yd²
Sherman Process (mulch)	KPN International, Inc. 19 Pebble Road Newtown, CT 06470 (203) 426-3639				Mulch	NA	NA	800.00/acre
Staff Liners	Staff Industries, Inc. P. O. Box 759 Upper Montclair, NJ 07043 (201) 744-5367				Liner	NA	NA	Not available
Supac 5NP (UV)	Phillips Fibers Corp. P. O. Box 66 Greenville, SC 29602 (803) 242-6600				Fabric	NA	NA	0.75/yd²

(continued)

Table 4-1 (continued)

Product name	Manufacturers' address and telephone numbers	Application method: Topically by truck	Application method: Topically by fixed mast	Application method: Mixed in place	Application method: Other	Application rate: Dilution	Application rate: Applied gal/yd²	FOB price before bilution, $
	Mulch, liners, fabrics (continued)							
Watersaver Liner	Watersaver Co., Inc. P. O. Box 16465 Denver, CO 80216 (303) 623-4111				Liner	NA	NA	Not available
	Windscreens							
Dusttamer	Julius Koch, Inc. P. O. Box A-995 New Bedford, MA 02741 (617) 995-9565				Wind-screen	NA	NA	2.07-2.95/linear foot, 3 ft. width
	Spray systems, foams							
Micro Foam	DeTer Company, Inc. 8 Great Meadow Lane E. Hanover, NJ 07936 (210) 386-1363		X			Not available	Not avialable	b
Omega Foam Dust Suppressant System	Valerin Technologies, Inc. Technical Center 87 Great Valley Parkway Great Valley Corp. Center Malvern, PA 19355 (215) 296-7322		X			Not available	Not available	b
Sani Blanket	Sani Foam, Inc. 1370 Logan Ave. Suite D Costa Mesa, CA 92626 (714) 557-5070	X				None	1-2" layer	0.11/ft²

(continued)

Table 4-1 (continued)

Product name	Manufacturers' address and telephone numbers	Application method: Topically by truck	Application method: Topically by fixed mast	Application method: Mixed in place	Application method: Other	Application rate: Dilution	Application rate: Applied gal/yd²	FOB price before bilution, $
Liquid chemicals (bitumens)								
AMS 2200	ARCO Mine Sciences 1500 Market Street P. O. Box 7258 Philadelphia, PA 19101 (215) 557-2000	X				4:1	0.5	1.75/gal
AMS 2300		X				1:1	0.75	1.85/gal
Coherex CRF	Witco Chemical Golden Bear Division P. O. Box 378 Bakersfield, CA 93302 (805) 393-7110	X				4:1	0.5	1.50/gal
Docal 1002	Douglas Oil Co. 3160 Airway Ave. Costa Mesa, CA 92626 (714) 540-1111	X				2:1	0.1	0.67/gal
Peneprime	Utah Emulsions Co. P. O. Box 248 North Salt Lake, UT 84054 (801) 292-1434	X				None	0.5	1.25/gal
Petro Tac P	Syntech Products Corp. 520 E. Woodruff Ave. Toledo, OH 43624 (419) 241-1215	X				5:1	0.25-0.75	1.55

(continued)

Table 4-1 (continued)

		Application method				Application rate		
Product name	Manufacturers' address and telephone numbers	Topically by truck	Topically by fixed mast	Mixed in place	Other	Dilution	Applied gal/yd²	FOB price before bilution, $
				Liquid chemicals (bitumens) (continued)				
Resinex	Neyra Industries, Inc. c/o Petroleum Products, Inc. P. O. Box 493 Valparaiso, IN 46383 (219) 465-1300	X				10:1	1.25-5.0	1.48/gal
Retain	Dubois Chemical Co. 3630 East Kemper Road Sharonville, OH 45241 (513) 769-4200	X				10:1	0.4	5.55/gal
				Liquid chemicals (adhesives)				
Bio Cat 300-1	Applied Natural Systems, Inc. 35 E. Lake Mead Drive Henderson, NV 89015 (702) 451-6010	X				66:1	2.0	19.95/gal
CPB-12	Wen-Don Corp. P. O. Box 13905 Roanoke, VA 24038 (703) 982-0561		X			10:1	1.0	7.50/gal
Curasol AK	American Hoechst Corp. Industrial Chemicals Route 202-206 North Somerville, NJ 08876 (201) 231-2000	X				22:1	0.2	6.26/gal

(continued)

Table 4-1 (continued)

Product name	Manufacturers' address and telephone numbers	Application method: Topically by truck	Application method: Topically by fixed mast	Application method: Mixed in place	Application method: Other	Application rate: Dilution	Application rate: Applied gal/yd²	FOB price before bilution, $
			Liquid chemicals (adhesives) (continued)					
DCL-40A DCL-1801 DCL-1803	Calgon Corp. P. O. Box 1346 Pittsburgh, PA 15230 (412) 777-8000	X X X	 X X			2-10:1 66-200:1 100-200:1	0.27-1.1 0.5-0.8 0.5-0.8	4.14/gal 9.20/gal 20.64/gal
DG-859 DG-873	Betz Laboratories, Inc. Somerton Road Trevose, PA 19047 (215) 355-3300	c c						
Dust Ban 6500 Dust Ban 7991 Dust Ban 8820	Nalco Chemicals Co. 2901 Butterfield Road Oak Brook, IL 60521 (312) 887-7500	X X 	X X			20-100:1 20-100:1 10:1	0.25-1.0 0.25-1.0 0.25-1.0	0.67/gal 9.20/gal 5.37/gal
Dust Bond 100	Research Products, Inc. 4222 North 39th Ave. Phoenix, AZ 85019 (602) 269-7891	X				None	0.17	0.40/gal
Dust-Set	Mateson Chemical Corp. 1025 East Montgomery Ave. Philadelphia, PA 19125 (215) 423-3200	X				500:1	0.17	8.00/gal
Dustbinder 124	Union Carbide Corp. Mining Chemicals 270 Park Ave. New York, NY 10017 (203) 794-2000	X				10-15:1	1.0	4.50/gal

(continued)

Table 4-1 (continued)

Product name	Manufacturers' address and telephone numbers	Application method: Topically by truck	Topically by fixed mast	Mixed in place	Other	Application rate: Dilution	Applied gal/yd²	FOB price before bilution, $
		Liquid chemicals (adhesives) (continued)						
Flambinder	Flambeau Paper Company P. O. Box 340 Park Falls, WI 54552 (715) 762-3231	X				5.5:1	0.5	0.15/gal
GCP 203	Betz Laboratories, Inc. Somerton Road Trevose, PA 19047 (215) 355-3300	a						
Lignosite	Georgia-Pacific Corp. P. O. Box 1236 Bellingham, WA 98227 (206) 733-4410	X				4:1	0.5	152.00/ton
M166	Dowell Division of Dow Chemical U.S.A.	X	X			16-20:1	0.4-0.6	5.10/gal
M167	P. O. Box 4378 Houston, TX 77210 (800) 645-9355	X	X			16-20:1	0.4-0.6	5.55/gal
Norlig A	Reed Lignin, Inc. 120 East Ogden Ave.	X				1.1	2.8	0.77/gal
Norlig 12	Suite 106 Hinsdale, IL 60521 (312) 887-9640	X				2.4 lb/gal	2.8	0.23/gal
Orzan AL-50	Crown Zellerbach Corp.	X				10:1	1.2-6.3	0.20/gal
Orzan DSL	Chemical Products Division	X				10:1	1.2-6.3	0.20/gal
Orzan GL-50	Camas, WA 98607 (206) 834-4444	X				10_1	1.2-6.3	0.20/gal

(continued)

Table 4-1 (continued)

Product name	Manufacturers' address and telephone numbers	Application method: Topically by truck	Application method: Topically by fixed mast	Application method: Mixed in place	Application method: Other	Application rate: Dilution	Application rate: Applied gal/yd²	FOB price before bilution, $
Liquid chemicals (adhesives) (continued)								
Res 661	Union Chemicals Division Union Oil Co. of Calif.	X				8:1	0.2	3.10/gal
Res 3078	14445 Alondra Boulevard La Mirada, CA 90638	X				8:1	0.2	3.61/gal
Res 4281	(714) 523-5120	X				8:1	0.2	4.04/gal
Rezosol 5411-B	E. F. Houghton & Co. Madison & Van Buren Aves. Valley Forge, PA 19482 (215) 666-4105	X				30:1	1.0	6.48/gal
SP-301	Johnson-March Corp. 3018 Market Street	X				None	0.25	2.15/gal
SP-400	Philadelphia, PA 19104 (215) 243-1700	X				None	0.25	3.95/gal
Soil Gard	Walsh Chemical Corp. 207 Telegraph Drive Gastonia, NC 28052 (704) 865-7451	X				5-15:1	0.25-0.8	9.09/gal
Soil-Sement	Midwest Industrial Supply Inc. P. O. Box 8431 Canton, OH 44711 (216) 499-7888	X				5:1	0.25	2.32/gal

(continued)

Table 4-1 (continued)

Product name	Manufacturers' address and telephone numbers	Application method: Topically by truck	Topically by fixed mast	Mixed in place	Other	Application rate: Dilution	Applied gal/yd²	FOB price before bilution, $
Liquid chemicals (adhesives) (continued)								
Suferm	Chevron Chemical Co. Sulfur Products 575 Market St. San Francisco, CA 94105 (415) 894-6723	X				None	0.2	1.88/gal
Terra Tack I	Grass Growers	X				0.5lb/gal	0.16	3.36/lb
Terra Tack III	424 Cottage Place	X				0.25lb/gal	0.33	3.95/lb
Terra Tack AR	Plainfield, NJ 07060 (201) 755-0923	X				0.25lb/gal	0.10	3.06/lb
WESLIG 120	WESCO Technologies, Ltd. P. O. Box 3880 San Clemente, CA 92672-1680 (714) 661-1142	X	X			6.7-10:1	0.25	0.42/gal
Woodchem LS	Woodchem, Inc. P. O. Box A Oconto Falls, WI 54154 (414) 846-2839	X				None	1.5	0.17/gal
55-03 Terraset	Celtite, Inc. 150 Carley Court			X		1.4-10:1	Not available	Not available
81-03 Polybind DLR	Georgetown, KY 40324	X				10:1	0.5	Not available
81-85 Polytack	(502) 863-6800	X				0.04lb/gal	0.26	Not available

(continued)

Table 4-1 (continued)

Product name	Manufacturers' address and telephone numbers	Application method: Topically by truck	Topically by fixed mast	Mixed in place	Other	Application rate: Dilution	Applied gal/yd²	FOB price before bilution, $
Liquid chemicals (salts)								
Calcium Chloride, Flake	Allied Chemical Corp. Industrial Chemicals Div. P. O. Box 6 Solvay, NY 13209 (315) 487-4000	X					1.0-1.5 lb	0.07/lb
Calcium Chloride, Liquid		X				None	0.4	0.225/lb
DP-10	Wen-Don Corp. P. O. Box 13905 Roanoke, VA 24038 (703) 982-0561	X				None	0.5	1.95/gal
Dust Ban 8806	Nalco Chemical Co. 2901 Butterfield Rd. Oak Brook, IL 60521 (312) 887-7500	X				None	0.25-0.5	0.22/gal
Dustgard ($MgCl_2$)	Great Salt Lake Minerals and Chemicals Corp. P. O. Box 1190 Ogden, UT 84402 (801) 731-3100	X				None	0.5	0.24/gal
Sodium Silicate (N)	The PQ Corporation P. O. Box 840 Valley Forge, PA 19482 (215) 293-7200	X				4:1	Not available	0.69/gal
Sodium Silicate (O)		X				4:1	Not available	0.71/gal

[a] NA = not applicable.

[b] Sold as turnkey systems.

[c] Application and price information is confidential.

Installation of a liner or fabric first requires careful site grading to eliminate rocks, large dirt clods, or sharp objects that might puncture the material. The site should also be graded so there are no low spots to collect liquid. This is particularly important with fabrics.

Liners and fabrics typically come in rolls of 12 feet or greater width. Seams are either overlapped, sewn, pinned, or attached with an adhesive. The edges are typically placed in a ditch and covered with soil.

4.4.2 Liquid Chemicals

The most diverse group of products are the liquid chemicals. Oil-based products, many of which are primarily marketed for haul road control, are listed first, followed by adhesives, which encompass a wide range of products. For example, Bio Cat 300-1 is marketed as a soil enzyme. Some, such as Flambinder, Lignosite, and Norlig A, are lignons; others are polymers of various sorts, such as AMSCO-RES 4281 (carboxylated styrene-butadiene copolymer), Curasol (synthetic resin), Genaqua (vinyl acetate resin), and Soil Seal (latex acrylic copolymer). The polymers are applied as a water-soluble liquid, but supposedly cure to a non-water soluble material.

Equipment required for application of liquid dust suppressants consists of a tank, pump, hose, and nozzle. The outfit can be on a truck or on a trailer that can be pulled by a truck. A portable generator is most often used to power the pump. Such rigs can be purchased or can be very easily assembled with readily available components.

The material is sprayed on well-graded soil with no soil lumps and no drainage puddles. Soil lumps will prevent the seal of soil around them. Standing water on a chemical will almost certainly reduce its effectiveness when the soil dries. It may be necessary to spray the chemical on in more than one application, as many soils will not absorb 0.5 gal/yd^2 without running off (PEDCo 1983). The bitumens are sometimes hard to keep in suspension, and thus require frequent mixing. Sometimes the addition of heat or chemicals is necessary. A lignon must never be put in a tank that has contained an emulsified asphalt or vice versa without thorough cleaning, as solids will form.

Once applied, the area should be fenced or somehow cordoned off. Any foot traffic, or vehicle traffic will reduce control effectiveness.

4.4.3 Mulches

Terra Tack I, Terra Tack III, Terra Tack AR, and Sherman Mulch can be impregnated with grass seed. These products contain a binder to hold the soil while the grass grows. Other similar products that are available are routinely used to vegetate highway excavations after construction. A detailed handbook on the use of materials for quick revegetation of soils of low-productivity soils is available (EPA 1975).

A mulch thrower is needed to distribute the mulch along the roadway. These can be rented. The Sherman Mulch is marketed as a product that only the manufacturer can apply. Before application, the site should be well graded and well drained.

4.4.4 Windscreens

Windscreens can be mounted either permanently or temporarily. When mounted permanently, they are mounted on permanent poles, the pole spacing of which depends on windscreen height and pole material. The product vendor makes pole spacing recommendations. The windscreen comes in 3- or 4-ft widths, so heights must be multiples of these widths. Windscreens also come in 10-ft by 10-ft panels mounted within an aluminum frame (at a much higher cost). These frames can be moved by two men. Other applications consist of attaching the screen to poles set in cement blocks. These cement blocks can be moved by a forklift. This makes a semipermanent installation. Other variations are also possible.

Specification of the screen size and spacing between the screen and the dust source is very important. The product vendor will also assist with these matters. The specifications are discussed under the following subsections.

Screen Height--

Height should be 2 to 4 feet above the source height. Too low a windscreen will actually increase downwind emissions because of wind shear.

Distance From Screen to Pile--

The downwind extent of sheltering is typically reported in terms of number of equivalent screen heights. The distance at which maximum windspeed reductions occur is 3 to 5 screen heights downwind.

Screen Length--

With winds exactly perpendicular to a screen, the sheltered area extends almost straight downwind from the two ends of the screen for a distance of 10 to 15 screen heights. The screen is extended beyond the edges of the area to be protected to compensate for changes in wind direction that occur over time. Recommended distances that a screen should extend beyond the area to be protected are 10 screen heights for a large field (greater than 10 screen heights in width) or one source width for a small source (less than 10 screen heights in width), such as a temporary storage pile.

Screen Porosity--

Air that passes through the windscreen fabric is referred to as "bleed flow", whereas air that is displaced upward over the screen is called "displacement flow". A more porous or permeable screen has higher bleed flow and less shear in the flow at the screen top. The higher porosity results in less reduction in mean windspeed immediately downwind of the screen, but a slower recovery to the upwind condition farther downwind of the screen. Above a porosity of 40 to 50 percent, large-scale eddying at the displacement flow and a zone of stagnant flow are no longer evident. Studies that investigated screen porosity found that a 50 percent porosity screen provides an optimum mix of wind velocity reduction, depth of shelter area, and low turbulence (Billman 1984).

Terrain Roughness--

The smoother the terrain on which a windscreen is erected, the greater is the reduction in windspeed downwind of the screen. Also, the zone of reduced windspeed becomes larger as upstream terrain roughness and air turbulence are decreased.

4.5 CONTROL EFFECTIVENESS

4.5.1 Exposed Areas

Several studies have examined wind erosion control from the standpoint of stabilizing mineral wastes and soil in connection with construction projects. No studies have been performed in conjunction with improvement of air quality or the control of dust emissions at hazardous waste sites. Only compressive strength, resistance to water erosion, and weatherability have been tested. Weathering tests consist of placing a weighed amount of soil of known moisture content in a sheet pan, spraying the soil with a dust-suppressant, exposing the sample to weather, and reweighing the pan with moisture correction. The soil loss is the loss in weight through the period. These tests give qualitative results, but are very representative of a large exposed area for the following reasons:

1) The soil is not naturally compacted in the baking pan.

2) The soil is much less thick than would be found in place. (The sample soil is less than 2 inches thick, and moisture could be expected to behave differently than on a large exposed area.

3) Using a hand spray bottle for suppressant application may not simulate the use of a high-powered sprayer on a large exposed area.

4) The before and after weights are compromised by dust and organic matter falling onto the test sheet.

None of the tests has involved ambient air sampling (Bureau of Reclamation, 1977, 1982; U.S. Army Engineer Waterways Experiment Station, 1977).

The only known testing with ambient air measurements was performed by PEDCo Environmental, Inc. (1984a). A chemical tracer (zinc oxide) was applied to 50-ft X 50-ft test plots, after which dust suppressants were applied. Sampling was performed for several weeks with passive air samplers. The dust collected from the ambient air was analyzed for the presence of zinc by atomic absorption spectroscopy. Zinc concentrations above the natural background level occurring in the soil (75 ppm) indicated failure of the crust formed by the dust suppressant.

Materials tested, dilution, and application rates are shown in Table 4-2. Selection of the products shown for testing did not mean they were more or less effective than other products available. These same products are listed in previously cited Table 4-1 of this report.

TABLE 4-2. EXPOSED AREA TEST PLOTS[a]

Dust suppressant name	Formulation	Application concentration	Application rate
Soil Seal	Latex acrylic copolymer	3%	1.0 gal/yd²
AMSCO-RES 4281	Carboxylated styrene-butadiene copolymer	20%	0.6 gal/yd²
Fiber Mat	Nonwoven geotextile	8 oz./yd²	3-12 foot rolls
Flambinder	Lignon sulfanate	17%	0.5 gal/yd²
Genaqua	Vinyl acetate resin	10%	0.2 gal/yd²
Curasol	Synthetic resin	3%	0.3 gal/yd²
M166/M167	Latex	7% (M166) + 0.2% (M167)	0.5 gal/yd²
CRF	Petroleum resin	25%	0.5 gal/yd²
Sherman Process (no grass seed)	Straw mulch bound with emulsified asphalt	--	--
Sherman Process (with grass seed)	Straw mulch bound with emulsified asphalt	--	--
Terra Tack I	Vegetable gum	0.3%	1.4 gal/yd²

[a] PEDCo 1984a.

Sixteen to 30 days after product application all crusts remained intact except the CRF product; 30 to 44 days after application only the M166/M167 crust was intact. The zinc tracer values increased through time, representing the progressive failure of the crust over time.

Visual examination of the plots during the course of the tests revealed almost immediate plant growth on the initially bare plots. The naturally occurring vegetation eventually overran all of the test plots, which totally destroyed the dust-controlling crusts and rendered the test plots indistinguishable from the surrounding study area. Even the fiber mat covering one plot was overtaken by vegetation that grew through the mat. A preemergent herbicide had to be used on most of the subsequent test plots. Although this markedly decreased the amount of vegetation, a few plants still appeared on each plot.

The problem of weed growth is illustrated in Table 4-3. This table indicates the presence of zinc in various elements of the test plot on July 20. The first column indicates the saltation (ambient air) catch sample. Values range from 55 to 121 ppm. The crust itself was of course very rich with zinc because that is where the tracer had been added. Values ranged from 163 to 544 ppm. Below the crust, values were at or near background. The soil around the weed stems, however, was apparently composed of destroyed crust, because zinc levels ranged up to 546 ppm, very near the crust levels. This loose soil around the weed stems was crumbly and of a very erodible texture that would be highly subject to wind erosion.

TABLE 4-3. OTHER RESULTS ON INITIAL EIGHT PLOTS TESTED JULY 20[a] (ppm)

Product	Saltation sample	Crustal sample	Subcrust sample	Soil around plant stems
Soil Seal	85	544	47	499
AMSCO RES 4281	121	413	79	546
Fiber Mat	55	291	50	263
Flambinder	90	433	46	546
Genaqua	67	366	69	239
Curasol	67	190	71	193
M166 & M167	72	163	91	108

[a] PEDCo 1984a.

An alternate procedure for dealing with vegetative growth would be to encourage it. Products are available that are temporary soil binders impregnated with grass seed. When grass was beginning to grow, the problem would be the same as that just described. Assuming a thick stand of grass did grow, control would probably not be 100 percent because there would always be some loose dirt between grass stems. Also, chemical dust suppressants sprayed on thick grass stands may not be effective because it would be difficult for the suppressant to reach the soil.

It is apparent that 100 percent effective control of wind-eroded particulates will require higher dust suppressant concentrations and/or multiple applications beyond the measures tested in the field study (PEDCo 1984a). Also, the effects of weather on vegetation must be considered. Precipitation is detrimental to those suppressants that are water-soluble (e.g., lignon sulfanate). Control of plant growth is essential if the crust formed by a dust-suppressing product is to remain intact.

4.5.2 Storage Piles

Various studies were found that evaluated the effectiveness of dust suppressants or windscreens in controlling fugitive dust from storage piles.

Chemical Dust Suppressants--

Two studies have evaluated the use of chemical dust suppressants. The first study used a wind tunnel placed over a coal pile for the evaluation (Midwest Research Institute 1983). Results of this study are listed in Table 4-4. Because coal differs greatly from contaminated soil, results are only partially applicable.

The other study evaluated the use of chemical dust suppressants on a topsoil pile (PEDCo 1984). Measurements were made with the RAM-1, a light-scattering instrument. A photograph of the crust formed 2 days after application is shown in Figure 4-1. Control efficiencies of more than 50 percent were estimated. Plots of emission rates indicated a lower rate of wind erosion than for an untreated pile, and wind erosion was not initiated until a higher threshold windspeed had been reached. The report concluded that the use of a chemical dust suppressant was superior to a windscreen in controlling dust, in terms of effectiveness, cost, and mobility around the pile.

The application of chemical dust suppressants to inactive piles achieved control efficiencies of at least 50 percent, however, no data indicate that a control effectiveness of 100 percent was ever approached. The reported data represent an undisturbed pile. Piles where material is being added or removed would have to be retreated. Material cost is quite low, however, and only the disturbed area would need to be retreated. For piles on which vehicles travel, control measures suitable to controlling vehicle reentrainment would have to be used, as opposed to the materials listed in this section.

Windscreens--

The use of windscreens has been proposed for reducing fugitive dust emissions from active and inactive piles. Several studies have been made of the effectiveness of this approach.

Figure 4-2 from one of these studies shows the reduction in windspeed velocity resulting from the use of a windscreen (Carner and Drehmel 1981). Reductions in windspeed velocity of 60 percent were measured at 10 screen heights. This does not necessarily mean a corresponding reduction occurred in fugitive dust emissions.

TABLE 4-4. RESULTS OF DUST SUPPRESSANT WIND TUNNEL STUDY

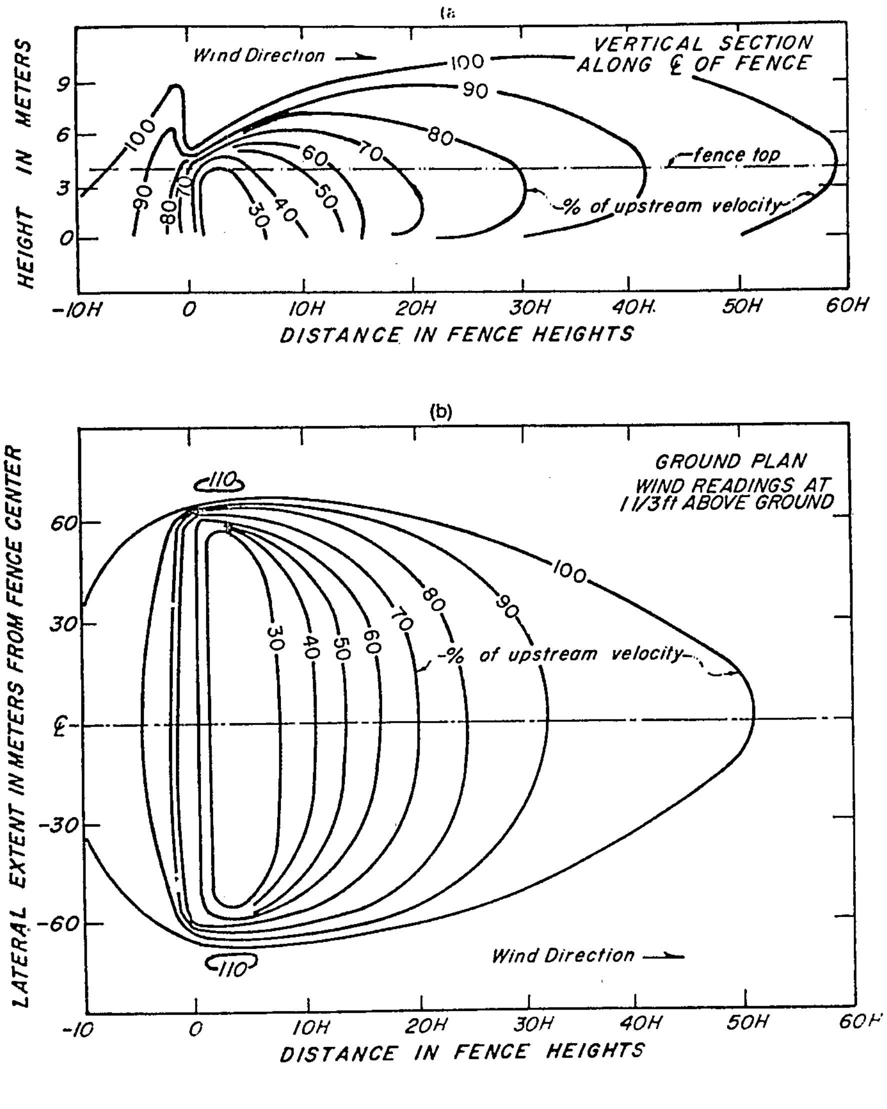
Product	Application concentration (%)	Application rate (liters/m²)	Control efficiency (%)[a]			Wind speed (m/s)
			2 days after application	4 days after application	60 days after application	
Coherex	17	3.4	-	-	89.6 (TP)[b] ~62 (IP, FP)[b]	15.0
Dow M-167	2.8	6.8	37.0 (TP) 0 (IP, FP)	-	-	14.3
			90.0 (TP) 68.8 (IP) 14.7 (FP)	43.2 (TP) 48.1 (IP) 30.4 (FP)	-	17.2

[a] Control efficiency measured 15.2 cm above an undisturbed steam coal surface (Coherex) and low-volatility coking coal surface (Dow).

[b] TP = total particulate; IP = inhalable particulate (<15 μm); FP = fine particulate (<2.5 μm).

FIGURE 4-1. CRUST FORMED BY CHEMICAL DUST SUPPRESSANT.

FIGURE 4-2. WIND VELOCITY PATTERN ABOVE A MOWN FIELD DURING A 17-m/sec WIND BLOWING AT RIGHT ANGLES TO A 4.9-m-HIGH WOOD FENCE 122 m LONG OF 50% POROSITY. (a) SIDE VIEW PROFILE. (b) PLAN VIEW PROFILE. (CARNES 1981)



Another study (TRC 1981b) measured wind reductions downwind of windscreens. With a 65 percent permeable windscreen and windspeeds of 3.0 m/s, wind reductions of 70 percent were measured immediately downwind, and wind reductions of 40 percent were measured 14 screen heights downwind. For a 50 percent permeable windscreen, values were comparable adjacent to the fence, but they were less farther downwind.

Another study measured reductions in fugitive dust emissions as well as reductions in windspeed (TRC 1982). The TSP emissions were sampled with high volume samplers. Testing was performed on a fly ash pile. The study concluded that the windscreen was effective both in reducing wind velocity approximately 66 percent under ordinary conditions and peak gusts by approximately 58 percent, and in reducing TSP and IP concentrations downwind by an average of 75 percent and 60 percent, respectively.

PEDCo (1984c) studied windscreens by using RAM-1 aerosol monitors and windspeed sensors interfaced with a portable computer to give real-time data results. The analysis indicated that the windscreen did not produce significant reductions in concentrations in the less that 10 micrometer respirable size range. The screen did reduce windspeeds by the amount anticipated, but this did not result in commensurate reductions in particulate concentrations coming from the pile. This probably occurred because wind erosion emission rates for particles in the less than 10-micrometer size range are fairly constant at windspeeds above the threshold of about 7 mph (hourly average). The additional emissions associated with high wind erosion losses at high windspeeds involve larger particles, which are not detected by RAM-1's. Although the windscreen may be effective in stopping or reducing the movement of these large particles, many of them do not stay airborne long because of their relatively large size; therefore, they present less threat of offsite exposure.

In summary, all studies are in fair agreement about reductions in windspeed resulting from the use of windscreens. Only two studies have measured reductions in dust concentrations as opposed to reductions in windspeed. The TRC (1982) study found reductions in the TSP size range of 60 to 75 percent. PEDCo studies of particles in the less than 10-micrometer respirable size range indicate no consistent benefits from the windscreen, but acknowledge that positive control efficiencies of larger size particles are likely. Control of the smaller size particles is more important, however because they are in the respirable range and because their small size allows allow the wind to transport them far offsite.

SECTION 5

FORMULATION OF A DUST CONTROL PLAN

Formulation of a dust control plan is an integral part of site cleanup planning. If the dust control plan is not formulated before cleanup begins but added on as an afterthought, it is possible that dust control measures will:

- Not be performed regularly.
- Not be adequately funded.
- Be performed in a less effective, begrudging way by employees saddled with the added responsibilities.
- Lack the necessary physical components (e.g., the addition of aggregate to unpaved roads, mud carryout wash stands, fencing for exposed areas).
- Not be adequately monitored by appropriate recordkeeping or ambient monitoring

The following tasks should be completed in the formulation of a dust control plan:

1) Identification of dust sources
2) Identification of controls
3) Development of implementation plan
4) Development of inspection, recordkeeping, and monitoring programs
5) Allocation of sufficient resources

Each of these work areas is described in this section.

5.1 IDENTIFICATION OF DUST SOURCES

The first task in the development of a Dust Control Plan is to identify all potential sources of fugitive dust. These sources (discussed earlier in Section 2) are listed below:

- Vehicle-related
  - Paved roads
  - Unpaved roads
  - Road shoulders along paved or unpaved roads
  - Mud carryout
  - Truck spillage
- From movement of dirt
  - Bulldozing
  - Loading into trucks
    - Travel area
    - Dump
  - Unloading from trucks
- Wind erosion-related
  - Exposed areas
    - Long-term (months)
    - Short-term (weeks)
    - Temporary (days)
  - Storage piles
    - Inactive
    - Active

After specific categories of fugitive dust have been identified, their location and period of existence should then be determined. Mapping the location of fugitive dust sources can be helpful. If the cleanup activity is staged or highly variable over time, a separate map for each stage may be needed.

5.2 IDENTIFICATION OF DUST CONTROL METHODS TO BE USED

Control method alternatives for each fugitive dust source are shown in Table 5-1 in the order of their usual effectiveness. None of these is 100 percent effective over the long term, with the possible exception of paving or placement of impermeable covers over exposed areas and piles.

The selection of which control measure to use can be a problem. Technical factors to aid in the decision-making process were presented in Section 2.

TABLE 5-1. POTENTIAL DUST CONTROL ALTERNATIVES

Fugitive dust source	Dust control method alternatives
Vehicle-related:	
Paved roads	Vacuum sweeping/flushing
Unpaved roads	Chemical sprays, water sprays, barring tracked vehicles
Road shoulders along paved or unpaved roads	Chemical sprays, water sprays
Mud carryout	Eliminating mud spots (regrade, gravel), tire washing
Truck spillage	Preventing overloading, covering loads, using trucks with tailgates vs. scows
Movement-of-dirt-related:	
Bulldozing	Area surfactant spray, area water spray
Loading into trucks	
Travel area	Area surfactant spray, area water spray
Dump	Area spray, spray curtain
Unloading from Trucks	Spraying material before loading into truck, spray bar
Wind Erosion Related:	
Exposed Areas	
Long-term (months/years)	Paving, covering, chemical sprays
Short-term (weeks)	Covering, chemical sprays, water
Temporary	Covering, chemical sprays, water
Storage piles	
Inactive	Covering, chemical sprays, water sprays, pile orientation
Active	Covering unused sections of pile, chemical sprays, water sprays, pile orientation

The basic steps in the decision-making involve determination of the following:

1) Which control measures would technically solve the dust-control problem irrespective of operational or financial constraints.

2) The minimum level of control acceptable.

3) Restraints caused by method of site cleanup, i.e., the operational feasibility of applying each control measure.

4) Financial feasibility of applying the control measure, including contractor equipment availability, material cost, and labor cost.

5.3 DEVELOPMENT OF THE IMPLEMENTATION PLAN

After dust sources and control measures have been identified, a list of resources necessary to implement the plan should be developed. This list would include:

1) Dust suppressant quantities

2) Application equipment (spray tanks, hoses, pumps, nozzles, hardware, road vacuum/flusher, calibrated spray trucks for unpaved roads and road shoulders, etc.)

3) Manpower (application, supervision, air quality monitoring, inspection, recordkeeping)

The resources must be identified for the whole cleanup job, but they also must be developed by smaller time increments. For average assignments, a weekly delineation probably will be adequate.

5.4 DEVELOPMENT OF INSPECTION, RECORDKEEPING, AND MONITORING PROGRAM

5.4.1 Inspection and Recordkeeping

A single person should be designated as Dust Control Manager and be made responsible for dust control activities and dust control inspections. The Dust Control Manager should report directly to the person in charge of the entire cleanup operation (not a shift foreman because activities span all shifts). If the cleanup operation runs more than one shift per day, the Dust Control Manager should have assistants on the off-shifts. The Dust Control Manager should continuously observe cleanup activities, and should inspect storage pile and exposed area treatments on a daily basis.

A recordkeeping system should be developed that includes the following: a listing of all inspections to be made on a daily basis, the person responsible for the inspection, blanks on forms on which to write the time and results of the inspection, and the person actually making the inspection. Inspection records should be submitted to and reviewed on a weekly basis by the person in charge of the site cleanup and the EPA site coordinator.

5.4.2 Monitoring

Depending on the severity of the contamination and the proximity to population and animals, an air quality monitoring program may be advisable. The Dust Control Manager should not be responsible for this program, which is essentially a policing function of the dust control program.

Very little monitoring of particulates has been performed to date. Emphasis has been on onsite monitoring of organics for worker protection and monitoring at the perimeter for liability protection. Monitoring has been performed with Tenax or charcoal tubes. Primary references describing monitoring around hazardous waste sites are:

1. Ambient Air Monitoring at Hazardous Waste Sites Vol. 1 - State of the Art Review, 1981; Vol. 2 - Guidelines for Quality Assurance and General Procedures, 1980. U.S. EPA, Office of Research and Development, Research Triangle Park, NC

2. Air Surveillance at Hazardous Materials Incidents. 1983. U.S. EPA, Office of Emergency and Remedial Response, Hazardous Response Support Division, Cincinnati, Ohio.

The following three methods can be used for particulate monitoring:

1) Tenax Tubes. Particulates trapped in the glass fiber, and the glass fiber is included in the thermal desorption process. When charcoal tubes are used, the particulates are caught in the glass fiber, but the fiber is discarded and not included in the analysis.

2) Personal Samplers. Personal samplers can be used with fiber filters for heavy metals analysis, or with membrane filters for organics. The membrane filter can be dissolved with a solvent for GC analysis.

3) Ambient Air Samplers (High-Volume, dichotomous, Size-Selective Inlet, Medium-Volume, Low-Volume). These samplers can be used with fiber or membrane filters for heavy metal or organic analysis.

Laboratory procedures for analysis of heavy metals are fairly standardized and reliable. Analyses of organics from filters is more difficult, and procedures vary with the organic being measured.

Placement of the monitors depends on the purpose of the sampling. Most monitoring protocols specify eight perimeter samplers. All hazardous pollutants are assumed to emanate from the sites. Monitored values are compared with critical exposure levels at the fenceline. The cleanup contractor often uses this method as liability protection against claims from area residents. Theoretically, if no critical exposure levels are measured at the fenceline, values further downwind will be below the critical exposure level.

An additional or alternate procedure would be to place samplers in population areas to measure exposure levels where the public lives. The drawback to this approach is determining with absolute certainty the origin of the organic or heavy metals monitored.

5.5 ALLOCATION OF SUFFICIENT RESOURCES

The preceding four steps will result in the identification of required equipment, materials, and labor. Fiscal resources should be allocated for the dust control program as part of the original project bid.

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APPENDIX A

EQUIPMENT DECONTAMINATION AND WORKER PROTECTION

EQUIPMENT DECONTAMINATION

Various pieces of equipment are used in the dust control program. For example, water wagons, calibrated sprayer trucks, road graders, drums, pumps, and hoses are used in road control; tanks, hoses, pumps, nozzles, windscreens, and trailers are used in wind erosion control; and, similar equipment is used for dust suppression during cleanup activities. For many of the used materials, the most economical approach would be to demolish them and remove them to a secure landfill. For major equipment, however, decontamination is the most economical approach.

Steam cleaning is by far the most frequently used decontamination method. The actual method selected, however, should be based on the nature of the contaminant, and it should be closely tied to the decontamination efforts throughout the site. The various methods of decontamination and the effectiveness of each are discussed in the following subsections of this appendix.

Steam Cleaning

Steam cleaning physically extracts contaminants from the surfaces of the equipment. The steam is applied with hand-held wands or automated systems, and the condensate is collected in a sump for treatment.

Steam cleaning is a relatively inexpensive and simple technique. Depending on the contaminant, decontamination may occur through thermal decomposition and/or hydrolysis. This technique is known to be effective only for surface decontamination, however. Removal of most contaminants is purely mechanical because of the limited solubility of many residues in water. Also, large volumes of contaminated water are generated.

Variations of this method include generating steam in the form of a water/acetone mixture to enhance contaminant solubility, mixing a wetting agent with the steam, superheating the steam, or using steam-jet systems for high fuel efficiency.

Effectiveness--

Removal or reaction of contaminants from the surface should be very good because steam can physically remove the contaminants from the surface; however, removal or reaction of contaminants from the subsurface is probably poor, as many contaminants have low solubilities in water. Theoretically, steam can be used to remove contaminants from the subsurface if the steaming effort is continued for a long period of time, but this has not been demonstrated. Paint may act as a barrier.

Equipment and Support Facilities Needed--

Steam cleaning requires steam generators, spray systems, collection sumps, and waste-treatment systems. The reliability, availability, and maintainability should be quite high, as commercial-scale steam cleaners are available from many manufacturers.

Minimal setup time is required, but special collection systems may have to be designed if floor sumps are inadequate. Existing sumps must be checked for leaks. A pumping system can be set up to remove condensate continuously.

Waste Disposal--

The contaminated wastewater collected in the sump must be treated to remove or destroy any waste residues. Pretreatment on site or in a municipal wastewater treatment facility will be needed. Treatment residues may be considered hazardous waste. (40 CFR Part 261 regulations and other pertinent EPA guidance should be consulted.)

Costs--

Utility and fuel costs should be low because steam is relatively inexpensive to generate. Equipment costs include steam cleaners ($2000 to $5000), spray systems, collection sumps, and waste-treatment systems. Material costs may include additives such as surfactants or acetone. Manpower costs may be high because steam must be applied to all surfaces and because more than one application may be necessary. A water rinse will probably be required. Automated steam wands can reduce labor costs, but they increase equipment costs.

Hydroblasting/Waterwashing (Benecke 1983; Marion 1980; Jones 1982)

A high-pressure (500 to 50,000 psi) water jet is used to remove contaminated debris from surfaces. The debris and water are then collected and thermally, physically, or chemically decontaminated.

Hydroblasting offers a relatively inexpensive, nonhazardous surface decontamination technique with off-the-shelf equipment. Variations such as hot or cold water, abrasives, solvents, surfactants, and varied pressures can be easily incorporated. Many manufacturers produce a wide range of hydroblasting systems and high-pressure pumps.

Hydroblasting may not effectively remove contaminants that have penetrated the surface layer. Also, large amounts of contaminated liquids will have to be collected and treated.

Effectiveness--

Hydroblasting is believed to remove surface contamination completely. On the average, this method removes 1/8 to 1/4 inch of concrete surface at the rate of 360 ft^2/hour. High pressures (10,000 to 50,000 psi) and chemical additives also can remove contaminants from below the surface; however, water may damage insulation and wooden surfaces. Other methods may be needed to remove/decontaminate remaining waste residues that have deeply penetrated surfaces through cracks and pores.

Equipment and Support Facilities Needed--

Hydroblasting requires a water-blasting system consisting of a high pressure-pump, hoses and nozzles, water collection sumps, water storage tanks, and conventional water pumps. Off-the-shelf equipment is used and the system is quite simple. Reliability, availability, and maintainability are high.

Before decontamination activities begin, existing sumps or water collection systems must be checked for leaks. Installation of sumps and external water storage tanks may be necessary.

Waste Disposal--

The removed surface debris and spent water must be collected in a sump system. Solids are separated by settling, and the liquid portion may be recyclable. All solids and used liquids should be considered contaminated and handled accordingly. Disposal of solids in a hazardous waste landfill will probably be required if these are not decontaminated. Incineration is a possible treatment option. The liquid also may require pretreatment to remove contaminants prior to its discharge to an NPDES-permitted wastewater treatment facility. Activated charcoal alone or combined with sand filtration may work, but this is expensive, and the filter and solids must be treated or disposed of as a hazardous waste.

Costs--

A hydroblaster can be powered by gas, electricity, or diesel fuel, so utility and fuel costs should be moderate. A 10,000-psi, 10-gpm diesel-powered pump with a trailer costs $27,138, and a wet sandblast mixing head is $542. A 5000-psi, 10-gpm diesel-powered pump with a trailer costs $19,125 (manufacturer's brochure). Other material costs to be incurred include those for water and solvents, surfactants, and abrasives (if added). Personnel costs could be high. Automated systems can decrease personnel costs, but will increase equipment costs.

WORKER HEALTH AND SAFETY

Training

All personnel engaged in activities at Superfund emergency or remedial sites should undergo various levels of orientation and training. Hazardous waste training courses can be developed in-house (under the direction of experts in the field), or workers may attend any number of commercial courses available throughout the United States. These commercial courses are sponsored by universities, private firms, and local, state and Federal agencies. Every course should have the following basic components: classroom training, hands-on field work, and periodic refresher training.

Medical Surveillance

The purpose of a medical surveillance program is to maintain a record of general worker health to ensure appropriate placement of workers in job categories, to prevent (or to detect at an early stage) any harmful effects of hazardous substances on workers, and to provide resources for emergency medical care and treatment. Responsibility for a medical surveillance program should be assigned to medical personnel who are knowledgeable in toxicology and experienced in occupational medicine. Program development should be coordinated with industrial hygienists, emergency response team members, safety professionals, or other persons involved in the overall site safety plan. Fragmentation of the medical management of employees or of individual medical records should be avoided, however.

The major components of a medical surveillance program are preassignment physicals, periodic medical exams, recordkeeping, exit exams at employment termination, and emergency medical care plans.

Personal Protective Equipment

Proper selection and use of personal protective equipment are crucial to the preservation of worker safety and health. Subpart I of OSHA Regulation 29 CFR 1910 states that "protective equipment...shall be provided, used, and maintained...wherever it is necessary by reason of hazards of processes or environment." Personal protective equipment is often the sole barrier separating workers from potentially hazardous substances during decontamination projects. Headgear, protective clothing, gloves, boots, goggles, and respirators are designed to permit safe work operations by preventing skin contact, dermal absorption, inhalation, and inadvertent ingestion of potentially toxic agents. Personal protective equipment is also designed to protect the worker from physical injuries such as eye wounds, bruises, abrasions, and lacerations. Four factors must be considered in the development of a program of personal protective equipment: 1) selection of appropriate equipment, 2) equipment distribution, 3) worker training, and 4) equipment decontamination and/or disposal procedures. Any personal protective equipment program should also meet the general requirements outlined by OSHA 29 CFR 1910, Subpart I.

Equipment Selection--

The hazards present at the decontamination site must be characterized before the proper personal protective equipment can be selected. The types, toxicity, and concentrations of contaminants must be defined. Points of potential high-risk contact (splashes, high atmospheric concentrations, etc.) during specific job operations should be identified when possible. The degree of hazard at the decontamination site will dictate the level of personal protective equipment required. The equipment necessary to protect the body against contact with known or anticipated chemical hazards can be divided into four categories, each affording a different level of protection (EPA 1982):

Level A requires the highest level of respiratory, skin, and eye protection. Level A protective equipment consists of:

- Pressure-demand, self-contained breathing apparatus approved by NIOSH and the Mine Safety and Health Administration (MSHA).
- Fully encapsulating chemical-resistant suit
- Coveralls*
- Long cotton underwear*
- Gloves (outer), chemical-resistant
- Gloves (inner), chemical-resistant
- Boots, chemical-resistant, steel toe and shank (depending on suit construction, worn over or under suit boot)
- Hard hat* (under suit)
- Disposable protective suit, gloves and boots* (over fully encapsulating suit)
- 2-way radio communications (intrinsically safe)

Level B is selected when the highest level of respiratory protection is needed but a lesser level of skin protection is sufficient. Level B protection is the minimum level recommended on initial site entries until the hazards are further defined. It consists of:

- Pressure-demand, self-contained breathing apparatus (MSHA/NIOSH-approved)
- Chemical-resistant clothing (overalls and long-sleeved jacket; coveralls; hooded, one- or two-piece chemical-splash suit; disposable chemical-resistant coveralls)
- Coveralls*
- Gloves (outer), chemical-resistant
- Gloves (inner), chemical-resistant
- Boots (outer), chemical-resistant, steel toe and shank

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* Optional

- Boots (outer), chemical-resistant (disposable)*
- Hard hat (face shield)*
- 2-way radio communications (intrinsically safe)

Level C is selected when the type of airborne substances is known and the criteria for air purifying respirators are met, as in the case of most building and equipment decontamination operations. Level C protective equipment consists of:

- Full-face, air-purifying, canister-equipped respirator (MSHA/NIOSH-approved)
- Chemical-resistant clothing (coveralls; hooded, two-piece chemical-splash suit; chemical-resistant hood and apron; disposable chemical-resistant coveralls)
- Coveralls*
- Gloves (outer), chemical-resistant
- Gloves (inner), chemical-resistant*
- Boots (outer), chemical-resistant, steel toe and shank*
- Boots (outer), chemical-resistant (disposable)*
- Hard hat (face shield*)
- Escape mask*
- 2-way radio communications (intrinsically safe)

Level D is selected when there are no respiratory or skin hazards. Level D protective equipment consists of:

- Coveralls
- Gloves*
- Boots/shoes, leather or chemical-resistant, steel toe and shank
- Boots (outer), chemical-resistant (disposable)*
- Safety glasses or chemical-splash goggles*
- Hard hat (face shield*)
- Escape mask*

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* Optional

When conditions are uncertain, the maximum level of personal protective equipment should be used. Also the equipment chosen should be able to handle the highest exposure conditions likely to be encountered during the scope of work. Personal protective equipment requirements for some chemicals are designated by government regulations. For example, the OSHA Asbestos Regulation (29 CFR 1910.1001) describes the types of respirators that must be used by workers occupationally exposed to asbestos fibers.

Specific details about performance characteristics of personal protective equipment are available from manufacturers . In addition, NIOSH has published several guides describing different types of personal protective equipment (including respirators) and their appropriate uses.

Equipment Distribution--

For effective management of a personal protective equipment program, a particular location or locations should be established as a center for all equipment distribution, storage, repair, and maintenance. Responsibility for these activities should be assigned to a specific individual or group of individuals, and all personnel should be made aware of the location of the personal protective equipment center. Checkout procedures for some safety devices, such as self-contained breathing apparatuses (SCBA), may be useful to track particularly hazardous operations. Extra equipment should be readily available in case of emergency or for use by site visitors.

During use, personal protective equipment is subject to physical damage as well as contamination with hazardous substances. Contamination must be removed from equipment prior to its reuse. If equipment is washed, the spent wash and rinse solutions are treated as contaminated waste. Damaged or non-reusable equipment also should be disposed of as contaminated waste. General guidelines for decontamination of personal protective equipment are presented in Part 7 of the "Interim Status Operating Safety Guides" (EPA 1982).

Site Safety Plan

The objective of a site safety plan is the establishment of standard operating procedures and guidelines to ensure that all facets of the decontamination operation are conducted in a safe and orderly manner. Depending on the situation, the responsibility for developing a site safety plan may lie with Federal agencies (OSHA, NIOSH), state agencies (mainly Departments of Health), site owners, or cleanup contractors. Because safety plans must be site-specific, they are subject to modifications by onsite supervisory personnel.

The site safety plan should appoint one individual as the site safety officer. This individual should be thoroughly knowledgeable of all Federal, state, and local governmental regulations and guidelines pertaining to the contaminant(s) at the site. The site safety officer may consider consulting other references (industrywide publications, private research documents, industrial hygiene organizations) that address the specific contaminants of concern. The site safety officer should be given complete control of the safety aspects of the cleanup operations and should have the authority to make on-the-spot decisions concerning job safety procedures. In addition, the safety officer should be responsible for reporting, documenting, and correcting any infractions of safety-related rules and should have the authority to shut down the job site if severe and/or chronic rule infractions occur.

Within the organization responsible for overall cleanup operations, a quality assurance/quality control (QA/QC) staff responsible for the monitoring of all site safety activities should be established. As part of their duties, QA/QC personnel should review the site safety plan before its implementation and follow up with periodic audits to assure compliance with the previously approved procedures.

The site safety plant should focus on the standard operating procedures necessary to ensure that all field work is conducted in an efficient yet safe manner. When a decontamination operation has been contractually agreed upon, an extensive review and investigation of the job site should be conducted before any field operations are begun. During this time, site safety personnel should familiarize themselves with the layout of the cleanup area and become thoroughly knowledgeable regarding the job specifications for the project, particularly those affecting worker health and safety.

In addition to an investigation of the job site, preoperational activities should include obtaining, verifying, and posting emergency phone numbers (fire department, hospitals, security); compiling a list of the type, amount, and toxicity of waste and potentially harmful substances found at the site; making sure an eyewash unit is available at the site; obtaining a first aid kit suitable for treating minor injuries that are likely to occur during cleanup operations; ensuring that all personnel who are to work at the site have had the required medical tests and training; notifying all applicable local, state, and Federal agencies; ensuring that all workers have been briefed on the hazards of the contaminant(s) they are about to encounter and are aware of the proper way to carry out decontamination procedures; and maintaining an appropriate supply of protective equipment on site.

When the initial safety precautions have been implemented, containment barriers should be constructed to separate contaminated areas from clean areas. An entry module, which provides for the safe entry and exit of those who must enter and leave contaminated areas, usually takes one of two forms: an airlock or a trailer. Airlocks, which can be constructed on sites, consist of prefabricated wooden structures and polyethylene sheeting. Whether a portable trailer with airtight connections or an airlock structure is used, the components are similar and provide like services. Both should include showers, locker areas, rest rooms, security offices, negative-air filtration systems, waste disposal operations, and a monitoring and recording station.

SAMPLING METHODS FOR DETERMINATION OF DECONTAMINATION

Swab Test

Materials--

The following materials are needed in this test:

Q-tip, wooden stem
Acetone, "distilled-in-glass" Nanograde
2-dram vial with Teflon-lined cap
Amber glass bottle, 1-pint
Plastic Nalgene bottle, 1-quart

Procedure--

Swab test procedures are as follows:

- Mark off five 2-inch-diameter circles distributed at the four corners and center of a 1-m^2 area for building surfaces or one 2-inch-diameter circle for vents and other surfaces.

- Dip a wooden stem Q-tip in a 2-dram vial containing 1.5 ml of acetone. Swab one circle at a time, dipping the Q-tip in the acetone before and after each circle is swabbed.

- When all circles have been swabbed, tightly seal the acetone-containing vial with a Teflon-lined cap and discard the used swab.

- Preserve the collected sample at 4°C.

- Prior to analysis, allow the sample to warm to ambient temperature.

- To compensate for possible solvent evaporation during transport, adjust the final volume of the sample with acetone to 1.5 ml.

- Analyze the sample for suspected contaminant.

- When resampling an area following surface decontamination, position the sampling grid 6 inches to the right of the initial sampling points or, if movement to the right is restricted, 6 inches downward.

Wet Wipe Test

Materials--

The following materials are needed in this test:

Cotton swab, degreased
Acetone, pesticide grade
Hexane, pesticide grade
Isooctane, pesticide grade
Metal clamp
Glass-stoppered glass jar
10-ml cone-shaped-bottom vial with glass stopper or Teflon-lined screw cap

Procedure--

Wet wipe procedures are as follows:

- Mark off a square area of approximately 0.25 m^2 on the surface to be wiped.

- While holding in a clean metal clamp, saturate a 10-g degreased cotton swab with 20 to 30 ml of a 1:4 acetone/hexane mixture.

- While still holding the cotton swab in the clamp, wipe the sampling area back and forth repeatedly in a vertical direction, applying moderate pressure.

- Turn the swab over and wipe back and forth in the horizontal direction.

- Store the used swab in a glass-stoppered glass jar until extraction can be performed.

- Extract the used swab with three fractions (200 ml each) of the 1:4 acetone/hexane mixture.

- Pool the three fractions and dry under vacuum.

- Clean the extraction residue by column chromatographic techniques.
- Store the dried sample from the final cleanup step in a 10-ml cone-shaped-bottom vial sealed with either a glass stopper or a Teflon-lined screw cap.
- Analyze the sample for suspected contaminants.

Dry-Wipe Test

Materials--

A 2.4-cm-diameter filter paper disk is required for this test.

Procedure--

Dry-wipe test procedures are as follows:

- Using the tip of the thumb, wipe a 2.4-cm-diameter filter paper disk in a Z or S pattern over a representative portion of the surface to be sampled. The length of the wipe should be 50 cm. (The pressure-bearing portion of the filter paper disk will be about 2 cm wide; therefore, the area of the surface sampled will be approximately 100 cm^2).
- Avoid contacting excess dirt when wiping an area.
- Test the sample with appropriate instruments for determining contamination.

Sump Sampling

Materials--

The following materials are required for sump sampling:

Wastewater vacuum pump sampler
Tygon tubing, 3/8-inch i.d.
Amber glass bottle, 500-ml
Polyethylene bottle, 1-liter
Rubber stopper

Procedure--

Procedures for sump sampling are as follows:

- Attach a clean piece of Tygon tubing (about 1 to 1.5 ft) to the silicone rubber tubing outlet of the sampler.
- Connect the other end of the Tygon tubing to the inlet tube in the stopper of the sample container (polyethylene bottle for heavy metal contamination, glass bottle for explosives contamination).
- Place the sample container at the bottom of the sampler and secure it with tape or padding.

- Close the sampler lid.
- Attach a second piece of Tygon tubing of sufficient length to reach the bottom of the sump to the silicone rubber tubing inlet of the sampler.
- Connect the strainer/weight to the other end of the Tygon tubing.
- Lower the strainer/weight-bearing end of the tubing into the sump.
- Set the volume selector control to the desired volume corresponding to the head height, and turn the pump switch to "auto".
- When the sample has been collected, open the sampler, remove the bottle, and replace it with an empty bottle.
- Remove the tubing assembly from the well.
- Flush out the sampler by running a large volume of distilled water through it.
- Clean the strainer/weight with lab glassware detergent and rinse with distilled water.
- Replace the Tygon tubing between sampling of wells to avoid cross-contamination of sump samples.
- Preserve the sample at 4°C. Prior to analysis, allow the sample to warm to ambient temperature.
- Filter the sample through a Whatman 2 filter to remove suspended insoluble material.
- Analyze the filtrate and residue for suspected contaminants.

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APPENDIX B. NON-AIR IMPACTS FROM THE USE OF DUST SUPPRESSANT MEASURES

INTRODUCTION

Although the use of dust suppressants is a means of preserving air quality, it is necessary to examine the effects dust control materials may have on non-air aspects of the environment. In this appendix, the effects of various dust control materials on surface water, ground water, wildlife, plants, and workers will be examined. The dust control materials are categorized as:

- Films, Liners, Fabrics, Windscreens
- Foam and Spray Systems
- Liquid Chemicals
  - Bitumens
  - Adhesives
  - Surfactants
  - Salts
  - Water

FILMS, LINERS, FABRICS, WINDSCREENS

The chemical compositions of films, liners, fabrics, and windscreens pose little or no threat to the environment. A nuisance may occur if the material is damaged and blows onto nearby property.

FOAM AND SPRAY SYSTEMS

Foam and spray systems are mechanical devices which deliver water amended with various surfactants. No environmental problems are associated with these systems other than those posed by the surfactants, and by use of large amounts of a liquid relative to water quality as discussed later.

LIQUID CHEMICALS

Bitumens

Bituminous substances are those derived from petroleum refining. These may be categorized as asphaltic compounds and petroleum resins. These compounds are generally inert unless contaminated by aromatics or other hazardous by-products of the petroleum refining process. They are applied as either emulsions in water or as solutions in an organic solvent. The relatively low solubility of asphaltics and resins in water limits their migration in either surface or ground water. Once applied, these materials form a good bond with soil particles; however, some migration may occur during a large precipitation event soon after application.

Low toxicity to plant life is evidenced by the fact that these compounds are used to hold mulches over seed beds. Acute oral toxicity tests conducted on Coherex, a petroleum resin mixture, showed the material to be practically non-toxic (LD_{50} > 16g/kg body wt.) (Bio-Technics, 1976). Workers should observe good personal hygiene when handling these products, especially in concentrated form. Eye protection, mist respirators, and protective clothing are suggested.

Adhesives

The category of adhesive dust control products is large and diverse. It includes such classes of compounds as synthetic resins, synthetic polymers (amides, acrylics, polyethers, vinyl polymers, polysulfides), and natural adhesives (lignin sulfonates, vegetable gums, soil enzymes). Little environmental effects data is available on the synthetic adhesives when used as dust control agents. Due to their adhesive nature, these compounds resist migration after application. Polysulfides may be toxic to aquatic organisms if allowed to enter surface water.

Vegetable gums and soil enzyme compounds have few adverse environmental effects. Vegetable gums are easily biodegradable and are often used in mulches to protect seed beds from erosion. Many of these same compounds are used as human food additives. Soil enzymes are extracted from soil bacteria and, when used properly, would be expected to cause few environmental problems. Lignin sulfonates may cause aesthetic problems in surface water due to discoloration. Toxic effects on aquatic organisms may also occur at high concentrations (7500 ppm). Due to its slow movement through soils, lignin sulfonate has little effect on ground water. It has been found to have no effect on seed germination and is essentially non-toxic (LD_{50} > 50g/kg body wt.). The FDA allows the use of lignin sulfonate as a binding aid in animal feed and as a component in paper and paperboard which comes into contact with aqueous or fatty foods (Bureau of Mines, 1982).

Workplace hazards vary with the type of compound. It is suggested that workers use protective clothing, eye protection, and appropriate respirators when handling these materials. Some of these products may be corrosive to skin and others may produce toxic compounds when burned or reacted with other materials. For instance, some acrylics may produce hydrogen cyanide when burned and polysulfides produce hydrogen sulfide when acidified.

Surfactants

As in the case of adhesives, the surfactants used in dust control comprise a large, diverse list. The three types of surfactants are cationic, anionic, and nonionic. A mixture of anionic and nonionic surfactants is most commonly used in dust control applications. There is evidence of adverse animal effects from exposure to certain surfactants (Hrabak 1982, Kocher-Becker 1981, Van Zutphen 1972) and care should be taken when handling the concentrated materials. Workers should wear protective clothing, eye
protection, and appropriate respirators.

SALTS

Due to their solubility, calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$) are capable of affecting the quality of surface and ground water. Since these salts are hygroscopic, they remain wet and movement by air is reduced. The salts therefore are transported through the environment by water where they exist as positive and negative ions. The calcium and magnesium ions are readily absorbed by the soil and generally will not migrate far from the point of application; however, the chloride ion is essentially unaffected by the soil and will move freely. Calcium and magnesium are abundant in natural waters and the amount added by dust control would be rather insignificant. Chloride is also found in natural waters but at much lower concentrations.

Salts may be toxic to plants at low concentrations depending upon plant species, age, season and other factors. Salts are transported to plants through the soil; therefore, plant mortality would depend upon proximity to the point of application. Aquatic organisms demonstrate a tolerance to high salt concentrations. Some species of freshwater fish have tolerated calcium chloride concentrations as high as 22,000 ppm. Bottom-dwelling organisms may suffer the most from salt contamination of still waters. The salt laden water has a higher density than fresh water and will tend to stratify on the bottom thereby subjecting these organisms to much higher salt concentrations. Terrestrial organisms are most likely exposed to salt contamination by oral means. They, too, demonstrate a tolerance to salts. A lethal oral dose in dogs was found to be greater than 2g/kg body weight (Bureau of Mines, 1982).

Like other terrestrial organisms, humans would most likely experience salt toxicity through oral administration. However, the dusts and mists created by handling large quantities of the salts could irritate eyes, respiratory system, or the skin. Protective clothing such as goggles, gloves, respirators should be used.

The silicates used in dust control are sodium salts of silicic acid and demonstrate a high pH in aqueous solution. Due to this high pH, these materials may damage living organisms upon direct contact. However, when applied as for a dust control purpose, the silicates are diluted and neutralized to a less hazardous state. These compounds ultimately decompose to silica and soluble sodium salts. When handling silicates in concentrated form, workers must wear protective clothing including goggles or face shields, gloves, and respirators. The materials will produce skin and eye irritation and will also form flammable hydrogen gas on prolonged contact with metals such as aluminum, tin, lead, and zinc.

WATER

Water alone is often used as a method of dust control and in most ordinary applications, would not pose an environmental threat. However, if applied to a contaminated site, water could cause problems by carrying contaminants off-site. This may occur in one of two ways: (1) water may dissolve contaminants from soil particles or (2) water may physically move contaminated soil particles. When dissolved, contaminants may enter ground water as well as surface water. Suspended particles will be transported by surface run-off, and sites awaiting clean-up may not have drainage containment facilities. During active clean-up procedures, surface drainage will most likely be contained; however, the use of water by itself as a dust control measure may necessitate larger more expensive drainage containment facilities. Also, water may leak from trucks or other equipment carrying contaminated soil off-site.

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